Real exchange rate volatility, financial crises and nominal exchange regimes

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Resumen

Este artículo examina los orígenes de la volatilidad del tipo de cambio real (RER) en ochenta países de todo el mundo durante el perido comprendido entre 1970 y 2011. Nuestro principal objetivo es exporar el papel jugado por el tipo de cambio nominal en sus distintas versiones y su comportamiento y efectos sobre la crisis finaciera explicado a través de la volatilidad RER. Para lograrlo empleamos dos procedimientos complementarios que consisten en detectar las rupturas estructurales en las series RER y descomponer la volatilidad en componentes transitorios y permanentes. Los resultados confirman que la volatilidad del tipo de cambio se incrementa en el periodo de la crisis financiera y detecta la existencia de una relación inversa entre el grado de flexibilidad del régimen del tipo de cambio y la volatilidad RER usando una clasificación *de facto* del tipo de cambio.
Palabras clave: Crisis financiera, Ruptura Estructural, Modelo de Componentes GARCH

Abstract

This paper examines the sources of real exchange rate (RER) volatility in eighty countries around the world, during the period 1970 to 2011. Our main goal is to explore the role of nominal exchange rate regimes and financial crises in explaining the RER volatility. To that end, we employ two complementary procedures that consist in detecting structural breaks in the RER series and decomposing volatility into its permanent and transitory components. The results confirm that exchange rate volatility does increase with the global financial crises and detect the existence of an inverse relationship between the degree of flexibility in the exchange rate regime and RER volatility using a *de facto* exchange rate classification.
Keywords: Financial Crisis, Structural Breaks, Component-GARCH Model
JEL Codes: G01, C22, C54, F33

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INDICE

1. Introduction

An important challenge to exchange rate theory is the solution to the puzzle that real exchange rates (RERs) are more volatile than what most models can account for. Moreover, there is a great disagreement in the finance literature about the behaviour of nominal exchange rate volatility under alternative exchange rate arrangements. Flood and Rose (1995) highlight empirically a positive link between exchange rate volatility and flexible exchange rate regimes while Valachy and Kocenda (2003) provide either positive or negative link according to the countries under investigation. Friedman (1953) argues that exchange rate volatility cannot be reduced by switching from floating to fixed exchange rates. Lastly, there is a strand of theoretical literature that supports that the financial integration may reduce exchange rate volatility (see, for example, Obstfeld, 1984), although the empirical studies on the effects of globalization on exchange rate volatility remain non-conclusive: while Krugman and Obstfeld (2003) showed that globalization lead to exchange rate fluctuations, Hau (2002) and Calderon (2004) find a positive effect of liberalization on the reduction of the RER volatility. Moreover, Dornbusch et al. (1995) and De Gregorio et al. (2000) suggest that independent of exchange regimes; financial integration can make countries vulnerable to the external shocks, while Coudert et al. (2011) show that, for most countries in their sample, exchange rate volatility increases more than proportionally with the global financial crises. This is especially relevant since, from a historical perspective, financial crises seem to be more like the rule rather than the exception (see Bordo et al., 2001 and Reinhart et al., 2010; among others).

The majority of the existing literature investigates the effects of exchange rate volatility on a number of macroeconomic variables, e.g. growth (Bagella et al., 2006) or trade (Baum and Caglayan, 2010). However, there is a lack of sufficient studies examining the determinants of exchange rate volatility.

This paper attempts to fill some of the gaps in the empirical literature on the links between RER volatility and nominal exchange rate regimes and financial crises. Using a comprehensive data set including developed and developing countries for the period 1970-2011, we examine whether the choice of exchange rate regime and the occurrence of a financial crisis are associated with structural beaks in RER volatility and whether they affect the permanent and transitory components of such RER volatility.

Regarding the relevance of nominal exchange rate regimes and financial crises in explaining structural breaks in RER volatility, we make use of two econometric methods for testing for structural breaks: the OLS-based tests to endogenously detect multiple structural breaks, as proposed by Bai and Perron (1998, 2003), and several procedures based on Information Criterion together with the so-called sequential procedure suggested by Bai and Perron (2003). Once these structural breaks in RER volatility are detected, we examine whether they are associated with major banking, currency and debt crises and whether they coincide with changes in nominal exchange rate regimes.

As for the evaluation of effects of nominal exchange rate regimes and financial crises on RER volatility, we employ the component GARCH model proposed by Engle and Lee (1999) to decompose RER volatility into a permanent long-run trend component and a transitory short-run component that is mean-reverting towards the long-run trend.

Ours results confirm that exchange rate volatility does increase with the global financial crises and suggest the existence of an inverse relationship between the degree of flexibility in the exchange rate regime and RER volatility using a de facto exchange rate classification to capture the policies implemented by countries regardless of the regime reported by the country's authorities.

The remainder of this paper is structured as follows.

Section 2 describes the econometric methodology adopted in this study. Section 3 presents the data and the empirical result, and Section 4 offers some concluding remarks.

2. Econometric Methodology

2.1. Structural Breaks

Bai and Perron (1998, 2003)[1] consider the following multiple linear regression with m breaks (m+1 regimes):

$$
\begin{aligned}
y_t &= x_t'\beta + z_t'\delta_1 + u_t, \qquad t = 1,\ldots,T_1, \\
y_t &= x_t'\beta + z_t'\delta_2 + u_t, \qquad t = T_1+1,\ldots,T_2, \\
&\vdots \\
y_t &= x_t'\beta + z_t'\delta_{m+1} + u_t, \qquad t = T_m+1,\ldots,T.
\end{aligned} \tag{1}
$$

In this model, y_t is the observed dependent variable at time t; $x_t \quad (p \times 1)$ and $z_t \quad (q \times 1)$ are vectors of covariates and $\hat{a}$ and $\ddot{a}_{\mathrm{j}} \quad (j = 1,\ldots,m+1)$ are the vectors of coefficients, respectively. Finally, u_t is the disturbance at time t. The break points $(T_1,\ldots,T_m)$ are unknown. The purpose is to estimate the unknown regression coefficients and the break points using a sample of T observations.

We consider a pure structural change model $(p = 0)$, where all the coefficients are subject to change, from the model in equation (1). In this sense, we specify each series as an AR(1) process and then, to detect multiple structural breaks in variance, we use the absolute value of the fitted residuals of the AR(1) models.[2] For this analysis we specify $z_t = \{1\}$.

To detect multiple structural breaks, we use the following set of tests developed by Bai and Perron (1998, 2003)[3]: the sup F type test, the double maximum tests and the test for ℓ versus $\ell + 1$ breaks. In first place, we consider the sup F type test of no structural breaks ($m = 0$) versus the alternative hypothesis that there are $m = k$ breaks. In second place, we employ the double maximum tests, UDmax and WDmax. They contrast the null hypothesis of no structural breaks against an unknown number of breaks given some upper bound M. Finally, we use the test for ℓ versus $\ell + 1$ breaks, the labelled sup $F_T(\ell + 1/\ell)$ test. The method involves the application of the $(\ell + 1)$ test of the null hypothesis of no structural change versus the alternative hypothesis of a single change. The test is applied to each segment containing the observations $\hat{T}_{i-1}$ to $\hat{T}_i$ $i = 1,\ldots,(\ell + 1)$. To run these tests it is necessary to decide the minimum distance between two consecutive breaks, h, that it, is obtain as the integer part of a trimming parameter, $\mathring{a}$, multiplied by the number of observations T (we use $\mathring{a} = 0.15$ and allow up to four breaks).

To select the dimension of the models, we follow the method suggested by Bai and Perron (1998) based on the sequential application of the sup $F_T(\ell + 1/\ell)$ test, the sequential procedure.

2.2. Permanent and Transitory Components

Engle and Lee (1999) proposed a "component-GARCH" (C-GARCH) model to decompose time-varying volatility into a permanent (long-run) and a transitory (short-run) component.

Consider the original GARCH model:

$$\sigma_t^2 = \omega + \alpha(\varepsilon_{t-1}^2 - \omega) + \beta(\sigma_{t-1}^2 - \omega) \qquad (2)$$

As can be seen, the conditional variance of the returns here has mean reversion to some time-invariable value, ω. The influence of a past shock eventually decays to zero as the volatility converges to this value ω according to the powers of (α+β). The standard GARCH model therefore makes no distinction

[1] We are particularly grateful to Bai and Perron for providing us with the GAUSS code for computations.

[2] Similarly, Stock and Watson (2002) use the absolute value of the fitted residuals of a VAR model to analyse changes in variance. Alternatively, Valentinyi-Endrész (2004) use the squared errors from a AR(1)-GARCH(1,1) model to compute changes in variance.

[3] For further analysis see Bai and Perron (1998, 2003).

between the long-run and short-run decay behavior of volatility persistence.

For the permanent specification, the C-GARCH model replaces the time- invariable mean reversion value, ω, of the original GARCH formulation in ŜIjdzI·űλ2ƴ (2) ǿλűK I· űλΥŜ ØI·ǋλI·ōfŜ Ŏ2ΥǕ2ƴŜƴű Ij$_{ű}$:

$$q_t = \hat{\omega} + \rho(q_{t-1} - \hat{\omega}) + \varphi(\varepsilon_{t-1}^2 - \sigma_{t-1}^2) \quad (3)$$

where, q_t is the long-run time-variable volatility level, which converges to the long-run time-invariable volatility level $\hat{\omega}$ according to the magnitude of ρ. This permanent component thus describes the long-run persistence behavior of the variance. The long-run time-invariable volatility level $\hat{\omega}$ can be viewed as the long-run level of returns variance for the relevant sector when past errors no longer influence future variance in any way. Stated differently, the value $\hat{\omega}$ can be seen as a measure of the 'underlying' level of variance for the respective series. The closer the estimated value of the ρ in equation (7) is to one the slower qt approaches $\hat{\omega}$, and the closer it is to zero the faster it approaches $\hat{\omega}$. The value ρ therefore provides a measure of the long-run persistence.

The second part of C-GARCH model is the specification for the short-run dynamics, the behaviour of the volatility persistence around this long-run time-variable mean, q_t:

$$\sigma_t^2 - q_t = \gamma(\varepsilon_{t-1}^2 - q_{t-1}) + \lambda(\sigma_{t-1}^2 - q_{t-1}) \quad (4)$$

According to this transitory specification, the deviation of the current condition variance from the long-run variance mean at time t ($\sigma_t^2 - q_t$) is affected by the deviation of the previous error from the long-run mean $(\varepsilon_{t-1}^2 - q_{t-1})$ and the previous deviation of the condition variance from the long-run mean $(\sigma_{t-1}^2 - q_{t-1})$. Therefore, in keeping with its GARCH theoretical background, the C-GARCH specification continues to take account of the persistence of volatility clustering by having the conditional variance as a function of past errors. As the transitory component describes the relationship between the short-run and long-run influence decline rates of past shocks values of (γ+λ) closer to one imply slower convergence of the short-run and long-run influence decline rates, and values closer to zero the opposite. The value (γ+λ) is therefore a measure of how long this short-run influence decline rate is.

Together, these two components of the C-GARCH model describe, just like the original GARCH formulation, how the influence of a past shock on future volatility declines over time. With the C-GARCH model however, this persistence is separated into a short-run and long-run component, along with the estimation of the underlying variance level once the effect of both components has been removed from a series. The long-run component provides a measure of volatility generated by traditional fundamental factors, while the short-run component represents transitory volatility conditioned by financial market considerations, such as the arrival of new information, speculation and hedging positions.

3. Data and Empirical Results

3.1. Data

We use monthly data of eighty real exchange rates from 1970:1 to 2011:12[4] taking from the International Monetary Fund's International Financial Statistics and the Federal Reserve Board's Financial Statistics.[5] We consider six sets of countries: American countries (Canada, Mexico, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Dominican Republic, Jamaica, Trinidad and Tobago, Argentina, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay and Venezuela); European countries (European Union-12, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Netherlands, Portugal, Spain, Sweden, United Kingdom, Czech Republic, Hungary, Poland, Norway, Russia, Switzerland and Turkey); Middle East countries (Israel, Jordan, Kuwait, Syria, Saudi Arabia); Oceania countries (Australia and

[4] The sample size for Nicaragua covers the period 1988:1-2011:12.

[5] Data collected by Mathew Shane, Economic Research Service, United States Department of Agriculture.

New Zealand); Asian countries (Bangladesh, India, Indonesia, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, China, Hong Kong, Japan, Korea and Taiwan) and African countries (Algeria, Egypt, Morocco, Tunisia, Benin, Cameroon, Congo, Cote d'Ivoire, Ghana, Kenya, Mozambique, Nigeria, Senegal, Sierra Leone, South Africa, Tanzania and Zambia).

All real exchange rate series have been corrected of outliers following the methodology developed by Gómez and Maravall (1996).[6]

Given that the countries in our sample present different exchange rate regimes that can change under the period studied, we have used the "natural fine classification" of Reinhart and Rogoff (2004), updated until December 2010 by Ilzetzki, Reinhart and Rogoff (2011), to distinguish between a wide range of *de facto* regimes: 1) no separate legal tender; 2) pre announced peg or currency board arrangement; 3) pre announced horizontal band that is narrower than or equal to +/-2%; 4) *de facto* peg; 5) pre announced crawling peg; 6) pre announced crawling band that is narrower than or equal to +/-2%; 7) *de factor* crawling peg; 8) *de facto* crawling band that is narrower than or equal to +/-2%; 9) pre announced crawling band that is wider than or equal to +/-2%; 10) *de facto* crawling band that is narrower than or equal to +/-5%; 11) moving band that is narrower than or equal to +/-2% (i.e., allows for both appreciation and depreciation over time); 12) managed floating; 13) freely floating; 14) freely falling; 15) dual market in which parallel market data is missing.

As the tables in Ilzetzki, Reinhart and Rogoff (2011) provide monthly data, we can identify the exact date of the change of regime.

Regarding the financial crisis dates, we make use the information provided by Laeven and Valencia (2008) and Reinhart (2010). The former covers all systemically important banking, currency and debt crises for the period 1970 to 2007 for 261 countries, while the later offers the individual timeline of public and private debts, banking, sovereign domestic and external debt crises, and hyperinflation, for 70 countries, from their independence to 2010.

3.2. *Empirical Results*

3.2.1. *Structural Breaks Results*

Tables 1a-f present the detected numbers and dates of structural breaks[7] and their connection with an economic event for our examined set of countries. Recall that these breaks are searched endogenously from the data and our procedure does not rely on pre-test information to determine them, thereby avoiding the possible problem of "data mining".

To facilitate the interpretation of Tables 1a-f, we have indicated with an arrow if volatility increases (↑) or decreases (↓) after the structural break identified as crisis episodes. As for the breakpoints associated with variations in the exchange rate regime, we have used the same convention, so an arrow pointing downwards (↓) would indicate the volatility decreases and an arrow pointing upwards (↑) would indicate the volatility decreases. Additionally, ↑* indicates the volatility increases when the nominal exchange rate goes from a more fixed regime to a more flexible one and ↓* indicates the volatility decreases when the nominal exchange rate goes from a more flexible regimen to a more fixed one.

Table 1a illustrates results for American countries. As can be seen, the break points vary from country to country in general, although we can derive four central messages. First, the detected changes in volatility could be associated with a change in the nominal exchange rate regime (NER) in around the 70% of cases.

[6] We have made computations using the Program TSW.

[7] In order to save space, the numerical results of Bai and Perron's tests are not reported in Table 1 but they are available upon request.

Table 1a. Structural Breaks in Volatility: Real Exchange Rates, America

Period: 1/1970-12/2011 **Specifications:** $z_t = \{1\}$ $q = 1$ $p = 0$ $\varepsilon = 0.15$ $m = 4$

	SP[a]	**Dates and Explanation**[b]
North		
Canada	2	Jun 1976: CSE; Nov 2002: NERc↑ *[c]
Mexico	3	Apr 1981:NERc↑*, SBC[b]↑,DC↑; Mar 1988: NERc↓*; Dec 1994: NERc↑*, SBC↑
Central		
Costa Rica	2	Jul 1977: CSE; Nov 1983: NERc↓*
El Salvador	2	Sep 1984: CSE; Jun 1993: CSE
Guatemala	1	Jan 1995: CSE
Honduras	3	Aug 1980: CSE Mar 1990:NERc↑*, CC↑ ; Dec 1998: NERc↓*
Nicaragua	2	Feb 1992: NERc ↓* Jul 1998: CSE
Panama	1	Dec 1992: CSE
Caribbean		
Dominican Republic	3	Jan 1985: NERc↑*, CC↑ ; Aug 1991: NERc↓ *; Jan 2005: NERc↓*
Jamaica	2	Jan 1983: NERc↑*, CC↑; Jul 1996: NERc↓*, SBC↓
Trinidad Tobago	1	May 1976: NERc↓*
South		
Argentina	3	Feb 1981: NERc↑*, SBC↑; Mar 1991: NERc↓*; Oct 2001: NERc↑*, SBC↑, DC↑
Brazil	1	Jul 1982: CC↑
Chile	2	Jun 1976: NERc↓*, SBC↓; Jan 2001: CSE
Colombia	1	Jan 1994: NERc↑*;
Ecuador	2	Mar 1982: NERc↑*, SBC↑, CC↑, DC↑; Apr 2001: NERc↓*
Paraguay	3	Mar 1985: NERc↑* ; Jan 1991: NERc ↓* ; Mar 2002: CC↑
Peru	3	Oct 1977: NERc↑* ; Aug 1986: NERc ↑* ; Jan 1990: CSE
Uruguay	1	Jun 1976: CSE
Venezuela	2	Jun 1978: SBC↑; Nov 1986: NERc↑*

Notes

a. SP: number of structural breaks selected by the sequential procedure by Bai and Perron (1998, 2003).
b. NERc: Nominal exchange rate regime change; SBC: Systematic Banking Crisis; CC: Currency Crisis; DC: Debt Crisis; CSE: Country Specific Event.
c. indicates the volatility increases and ↓ indicates the volatility decreases after the structural break identified as crisis episodes.
d. * indicates the volatility increases when the nominal exchange rate goes from a more fixed regime to a more flexible one and ↓* indicates the volatility decreases when the nominal exchange rate goes from a more flexible regimen to a more fixed one.

Table 1b. Structural Breaks in Volatility: Real Exchange Rates, Europe

Period: 1/1970-12/2011 **Specifications:** $z_t = \{1\}$ $q = 1$ $p = 0$ $\varepsilon = 0.15$ $m = 4$

	SP[a]	Dates and Explanation[b]				
European Union						
EU-12	2	Jan 1980: NERc↑* ;	Sep 1992: EMSC			
Austria	2	Jul 1980: NERc↑ ;	Sep 1992: EMSC			
Belgium	2	Jan 1980: CSE;	Sep 1992: EMSC			
Denmark	2	Jan 1980: NERc ↑;	Sep 1992: EMSC			
Finland	2	Jan 1980: CSE;	Sep 1992: EMSC			
France	2	Mar 1979: NERc↑;	Sep 1992: EMSC			
Germany	2	Jan 1980: CSE;	Sep 1992: EMSC			
Greece	1	Jul 1981: NERc↑*;				
Italy	2	Jan 1980: CSE;	Sep 1992: EMSC			
Ireland	2	Mar 1979: NERc↑ * ;	Sep 1992: EMSC			
Netherlands	2	Jan 1980: CSE;	Sep 1992: EMSC			
Portugal	1	Aug 1993: NERc ↓*;				
Spain	1	Apr 1978: SBC↑*;				
Sweden	1	Dec 1991: SBC↑*;				
United Kingdom	3	Apr 1979: CSE;	Sep 1992: EMSC, NERc↑* ;	Mar 2003:CSE		
Central and Eastern						
Czech Republic	2	Aug 1981: NERc↑ *;	Mar 1994: NERc↑*			
Hungary	2	Jun 1979: NERc↓* ;	Aug 2005: NERc↓*			
Poland	1	Oct 1977: NERc↑*				
Others						
Norway	1	Sep 1980: CSE				
Russia	4	Aug 1981: CSE;	Jan 1992: NERc↑*;	Aug 1998: NERc↑*, RFC↑ ;	Aug 2005:NERc↑*	
Switzerland	2	Jul 1977: CSE;	Sep 1993: CSE			
Turkey	2	Jun 1994: CSE;	Sep 2000: SBC↑*			

Notes

a. SP: number of structural breaks selected by the sequential procedure by Bai and Perron (1998, 2003).

b. NERc: Nominal exchange rate regime change; RFC: Russian Financial Crisis; SBC: Systematic Banking Crisis; CC: Currency Crisis; DC: Debt Crisis; EMSC: European Monetary System Crisis; CSE: Country Specific Event.

c. ↑ indicates the volatility increases and ↓ indicates the volatility decreases after the structural break identified as crisis episodes.

d. ↑* indicates the volatility increases when the nominal exchange rate goes from a more fixed regime to a more flexible one and ↓* indicates the volatility decreases when the nominal exchange rate goes from a more flexible regimen to a more fixed one.

Table 1c. Structural Breaks in Volatility: Real Exchange Rates, Middle East

Period: 1/1970-12/2011 **Specifications:** $z_t = \{1\}$ $q = 1$ $p = 0$ $\varepsilon = 0.15$ $m = 4$

	SP[a]	Dates and Explanation[b]		
Israel	3	Oct 1977: NERc↑*, SBC↑ ;	Oct 1992: CSE;	Nov 2001: CSE
Jordan	3	Feb 1975: NERc↑*;	Feb 1990: NERc↓*, SBC↓, CC↓, DC↓;	Aug 1995: NERc↓*
Kuwait	1	Sep 1992: CSE		
Syria	1	Oct 2004: CSE		
Saudi Arabia	3	Sep 1978: CSE	Jun 1989: CSE	Dec 2003: CSE

Notes
a. SP: number of structural breaks selected by the sequential procedure by Bai and Perron (1998, 2003).
b. NERc: Nominal exchange rate regime change; SBC: Systematic Banking Crisis; CC: Currency Crisis; DC: Debt Crisis; CSE: Country Specific Event.
c. ↑indicates the volatility increases and ↓ indicates the volatility decreases after the structural break identified as crisis episodes.
d. ↑* indicates the volatility increases when the nominal exchange rate goes from a more fixed regime to a more flexible one and ↓* indicates the volatility decreases when the nominal exchange rate goes from a more flexible regimen to a more fixed one.

Table 1d. Structural Breaks in Volatility: Real Exchange Rates, Oceania

Period: 1/1970-12/2011 **Specifications:** $z_t = \{1\}$ $q = 1$ $p = 0$ $\varepsilon = 0.15$ $m = 4$

	SP[a]	Dates and Explanation[b]
Australia	1	Nov 1982: NERc*
New Zealand	1	Mar 1985: NERc *

Notes
a. SP: number of structural breaks selected by the sequential procedure by Bai and Perron (1998, 2003).
b. NERc: Nominal exchange rate regime change; SBC: Systematic Banking Crisis; CC: Currency Crisis; DC: Debt Crisis; CSE: Country Specific Event.
c. ↑ indicates the volatility increases and ↓ indicates the volatility decreases after the structural break identified as crisis episodes.
d. ↑* indicates the volatility increases when the nominal exchange rate goes from a more fixed regime to a more flexible one and ↓* indicates the volatility decreases when the nominal exchange rate goes from a more flexible regimen to a more fixed one.

Table 1e. Structural Breaks in Volatility: Real Exchange Rates, Asia

Period: 1/1970-12/2011 **Specifications:** $z_t = \{1\}$ $q = 1$ $p = 0$ $\varepsilon = 0.15$ $m = 4$

	SP[a]	**Dates and Explanation**[b]
South		
Bangladesh	3	Mar 1976: CC↑; Oct 1982: CSE; Jul 1994: CSE
India	3	Jul 1979: NERc ↓*; Jan 1999: AFC ↑*; Dec 2004: NERc↑*
Indonesia	4	Mar 1976: CSE; Apr 1985: CSE Jul 1997: NERc↑*,AFC (SBC)↑; Aug 2003: CSE
Malaysia	2	Jul 1998: NERc↑*, AFC (CC)↑ ; Jul 2005: CSE
Pakistan	1	Jun 1982: NERc↓
Philippines	1	Jul 1997: NERc↑*, AFC (SBC)↑
Singapore	1	Jul 1997: AFC↑*
Sri Lanka	3	Nov 1981: NERc ↓*; Sep 1989: NERc↑, SBC↑; Dec 2004: CSE
Thailand	1	Jul 1997: NERc, AFC (SBC, CC) ↑
North		
China	4	Aug 1977: CSE; Dec 1984: CSE; Jan 1994: NERc ↓*; Jun 2005: CSE
Hong Kong	2	Jun 1977: CSE; Oct 1983: NERc↓*
Japan	2	Nov 1977: NERc ↑*; Jan 2000: CSE
Korea	2	Nov 1985: SBC ↓; Nov 1997: NERc↑*, AFC (SBC)↑
Taiwan	1	Jul 1985: CSE

Notes

a. SP: number of structural breaks selected by the sequential procedure by Bai and Perron (1998, 2003).

b. NERc: Nominal exchange rate regime change; AFC: Asian Financial Crisis; SBC: Systematic Banking Crisis; CC: Currency Crisis; DC: Debt Crisis; CSE: Country Specific Event.

c. ↑indicates the volatility increases and↓ indicates the volatility decreases after the structural break identified as crisis episodes.

d. ↑* indicates the volatility increases when the nominal exchange rate goes from a more fixed regime to a more flexible one and ↓* indicates the volatility decreases when the nominal exchange rate goes from a more flexible regimen to a more fixed one.

Table 1f. Structural Breaks in Volatility: Real Exchange Rates, Africa

Period: 1/1970-12/2011 **Specifications:** $z_t = \{1\}$ $q = 1$ $p = 0$ $\varepsilon = 0.15$ $m = 4$

	SP[a]	Dates and Explanation[b]
North		
Algeria	2	Oct 1980: CSE; Mar 1994: NERc↓, CC↓
Egypt	3	Jan 1979: CC↑ May 1984: DC↑ Oct 1991: NERc↓*, SBC↓
Morocco	0	
Tunisia	0	
Subshaharan		
Benin	1	Dec 1979: CSE
Cameroon	2	Aug 1980: CSE; Dec 1994: NERc↓*
Congo	1	Mar 1976: NERc↑*, CC↑
Cote d'Ivoire	1	Mar 1994: CC↓
Ghana	3	Nov 1976: CSE; Sep 1987: NERc↓ *; Aug 2000: CC↓
Kenya	1	Dec 1978: NERc↑*;
Mozambique	3	May 1976: CSE; Nov 1987: SBC↑, CC↑; Feb 1996: CSE
Nigeria	3	Sep 1984: NERc↑; Mar 1996: NERc↓*, CC↓; Jul: 2005: CSE
Senegal	1	Nov 1994: NERc↓*, CC↓
Sierra Leone	2	May 1983: CC↑ ; Feb 1990: SBC↓, CC↓
South Africa	2	Jan 1979: NERc↑; Nov 1989: SBC↑
Tanzania	2	Jan 1979: NERc↑; May 2001: CSE
Zambia	3	Jul 1976: NERc↑* ; Jul 1983: NERc↑*; Apr 1995: SBC↓, CC↓

Notes
a. SP: number of structural breaks selected by the sequential procedure by Bai and Perron (1998, 2003).
b. NERc: Nominal exchange rate regime change; SBC: Systematic Banking Crisis; CC: Currency Crisis; DC: Debt Crisis; CSE: Country Specific Event.
c. ↑ indicates the volatility increases and ↓ indicates the volatility decreases after the structural break identified as crisis episodes.
d. ↑* indicates the volatility increases when the nominal exchange rate goes from a more fixed regime to a more flexible one and ↓* indicates the volatility decreases when the nominal exchange rate goes from a more flexible regimen to a more fixed one.

Second, we observe that in 13 cases out of total 40 detected structural breaks there is evidence in favour of a financial crisis: a systematic banking crisis (SBC) and/or a current crisis (CC) and/or a debt crisis (DC).

Third, in 11 of these 13 cases, the occurrence of a financial crises is accompanied by a modification in the nominal exchange rate regime, from a fixed regime to a more flexible one. In particular, in Mexico, the first detected structural break, in April 1981, could be associated with a SBC and a DC and a change in the nominal exchange rate regime from a de facto peg to United States dollar to a *de facto* crawling peg to United States dollar. Moreover, in February of 1982, the nominal exchange regime varies to freely falling/ managed floating regimes. The same happens for the detected structural break in December 1994: the SBC took place join with a modification in the nominal exchange rate regime from a pre announced crawling band around United States dollar to freely falling/ freely floating regimes.

For Honduras, in March 1990 took place a CC join with a change in the nominal exchange rate, in particular, from a *de facto* crawling band around United States dollar (parallel market, multiple rates) to a freely falling and a *de facto* crawling band around United States dollar.

This regularity is observed again in the case of the Dominican Republic, where in January 1985 one structural break is located and could be associated with a CC and a variation in the nominal exchange rate regime (from a managed floating –dual market– regime to a freely falling/managed floating regime). The same is observed for Jamaica, where we detect two structural breaks: in January 1983 associated with a CC and a change in the nominal exchange rate regime from a peg to United States dollar to a *de facto* crawling band around United States dollar -dual market- and in July 1996 related with a SBC and change in the nominal exchange rate regime from a *de facto* crawling band around United States to a *de facto* crawling peg to United States dollar.

As for Chile we detect one structural break associated with a SBC and an alteration in the nominal exchange rate regime from a freely falling/multiple exchange rates regime to a freely falling/crawling peg to United States dollar.

Regarding Ecuador, in March 1982 took place simultaneously a SBC, a CC and a DC join with a change in the nominal exchange rate regime from a peg to United States dollar regime to a freely falling/ managed floating –dual market– regime.

In the case of Argentina, we find two structural breaks associated with a financial crisis and a switch in the nominal exchange rate regime at the same time. Specifically, in February 1981 took place a SBC and a change from a pre–announced crawling peg to United States dollar/freely falling regime (the so-called “Tablita Inflation Stabilization Plan”) to a freely falling/freely floating/dual market regime and in December 2001 where there were a SBC and a CC join with a variation in the nominal exchange rate regime (from a currency board/peg to US dollar to a freely falling-de facto-dual market).

The results for Paraguay suggest two structural breaks in RER volatility related to modifications in the nominal exchange rate regime (one in March 1985, where there was a transition from a managed floating regime to a freely floating regime, and another in January 1991, moving from a freely falling regime to a *de facto* crawling peg to US dollar) and one structural break connected with a CC in March 2002 following a deep institutional instability and economic uncertainty.

Table 1b shows the findings for Europe. In particular, for the aggregated EU-12 and the European Union countries individually, two common breaks have been located: at the end 1970s or beginning of 1980s that could be associated with a change in the nominal exchange rate regime (i.e. from a *de facto* moving band around Deutsche Mark to a *de facto* moving peg to Deutsche Mark) and in September of 1992, associated with the turbulence of the European Exchange Rate Mechanism (ERM), leading to the temporarily suspension of the sterling and the lira participation, the devaluation of several currencies, the abandonment of unilateral currency pegs to the ERM by Sweden and Finland, and the widening of the fluctuations bands.

Regarding Central and Easter European countries, the structural breaks detected in RER volatility are all connected with changes in nominal exchange rate regimes. In the case of the Czech Republic, they are associated with the introduction in August 1981 of a peg regime based on a five-currency basket and changes in exchange rate targeting and conventional fixed parity in March 1994. For Hungary, there is evidence of structural break in June 1979 and in August 2005, coinciding with major modifications in monetary and exchange rate policies. Concerning Poland the structural break detected in October 1977 could be associated with Poland modifications in external monetary operations.

Finally, Russia exhibits four structural breaks and, in particular, the detected one in August 1998 could be associated with the Russian financial crisis (SBC, CC, DC at the same time) and with the prices and interest rates liberalization and the convertibility of the ruble in January 1992 and with a change in the nominal exchange rate regime from a pre announced crawling band around United States dollar to a freely falling regime (August 2005).

Table 1c offers the results for Middle East countries. For Israel, the break detected in October 1977 is associated with a SBC and with a nominal exchange rate regime change (from a freely falling/managed floating/parallel market/multiple exchange rates to a freely falling/managed floating).[8]

For Jordan, the three detected structural breaks are associated to a change in the nominal exchange rate regime. Moreover, the break detected in February of 1990 is related with a financial crisis (SBC, CC and DC at the same time).

Regarding Australia and New Zealand (Table 1d), one structural break is detected in each country and can be associated to a nominal exchange rate regime.

Table 1e presents the results for Asian countries. First, we can observe that in almost the 50% of cases (14/30) the detected change in volatility could be related with a change in the nominal exchange rate regime. Second, there is a common break in 1997 when the Asian financial crisis starts and the years 1998 and 1999 that could be associated with this crisis too. Third, ten structural breaks could be explained by a financial crisis (a SBC and/or a CC and/or a DC). Finally, in six out of these ten cases the change in the nominal exchange rate regime occurs at the same time that a crisis occurs. In particular, for Sri Lanka we locate a structural break in September 1989 associated with a SBC and a change in nominal exchange rate regime from a peg to United States dollar to a *de facto* crawling peg to United States dollar. For Thailand the structural break detected in July 1997 could be associated with both a SBC and a CC and a change from a *de facto* peg to United States dollar regime to a freely falling/freely floating regime. For Malaysia we find one structural break in September 1998 associated with both a CC and a change in the nominal exchange rate regime (from freely floating to a peg to United States regime). In addition, we find a break in 1997 for Indonesia, Philippines and Korea related with a SBC and a change in the nominal exchange rate simultaneously (in Indonesia from a *de facto* crawling peg to United States dollar regime to a freely falling/freely floating

[8] Multiple rates abolished and the peg to a basket of currencies discontinued.

regime; in Philippines from a *de facto* peg to United States dollar regime to a freely falling/freely floating regime, and in Korea from a *de facto* crawling peg to United States dollar to a freely falling regime).

Table 1f exhibits the results for Africa. Findings seem to indicate, first, that in around the 50% of cases the detected break in volatility can be associated with a change in the nominal exchange rate regime. Second, fourteen out of thirty total detected structural breaks could be related with a financial crisis, mostly with a currency crisis (in 12 cases). Finally, in six out of fourteen cases a financial crisis and a change in the nominal exchange rate regime occur simultaneously. This is observed in Algeria (in March of 1994 a CC took place join with a change from a managed floating/ parallel market regime to a freely falling/managed floating regime); in Egypt (in October 1991 there were a SBC and a change from a *de facto* crawling band around United States dollar regime to a *de facto* moving peg to US dollar regime); in Senegal (a CC and a change in the nominal exchange rate regime occurs from a peg to French franc/freely falling to a peg to French franc in November 1994); in Cameroon (in December 1994 took place a CC and A change from a peg to French franc regime to a peg to French franc/ freely falling regime); in Nigeria (in March 1996 occurred simultaneously a CC and a change from a freely falling/managed floating/dual market regime to a managed floating/dual market and, finally, in Congo (in March 1976 took place at the same time a CC and a change in the nominal exchange rate regime from a freely falling/managed floating/parallel market to a freely falling/freely floating).

As can be seen in Tables 1a-f, there is a set of breaks that can be associated with specific economic events of each examined country (that we have denoted as country specific events, CSE).

All in all, findings from our structural breaks analysis suggest several empirical regularities. First, our results seem to indicate that exchange rate do regimes really matter, as we obtain evidence in favour of nominal regimes affecting RER variation. Second, we detect, in almost all cases, the existence of an inverse relationship between the degree of flexibility in the exchange rate regime and RER volatility, as well as an increase in RER volatility after a financial crisis in almost all cases. Third, we have documented an alteration in the nominal exchange rate regime towards a more flexible one after the event of a crisis.[9] This result is in line with Fornaro (2011), who claims the superiority of flexible exchange rate regimes compared to pegs both for the purpose of crisis times stabilization and as crises prevention devices. Finally, while two of the strongest financial crises, the Russian and Asian financial crises, have been detected using the procedure by Bai and Perron (1998, 2003), there is no evidence of a significant change in RER volatility around 2007 or 2008 capturing the recent global financial crisis. This could be related to the fact that various countries made used of policy interference in foreign exchange markets, such as intervention and capital controls to restrain tensions in the foreign exchange markets (see, e. g., Deutsche Bundesbank, 2010). Nevertheless, it is worth noting that institutional idiosyncrasies or major economic events are still at play given the heterogeneity of break points detected across countries since we have detected many country specific events. The reason for this heterogeneity is reserved for future research.

3.2.2. Permanent and Transitory Components

<u>Results</u>

Tables 2a-f report coefficient estimates for the C-GARCH models obtained by maximum likelihood for each real exchange rate. Table 3 exhibits a summary of results with the numbers and percentages of significant coefficient estimates.

For American countries, regarding the permanent component, the long-run average volatility ($\hat{\omega}$) is significant in nine out of the twenty cases examined. The coefficient $\hat{\rho}$ is significant for all countries at the 1% of significant, confirming the presence of long-

[9] Except for in Malaysia, Egypt and Senegal.

Table 2a. Volatility C-GARCH Model Estimates: America

	Permanent Component				Transitory Component			Wald Tests[c]	
	$\hat{\omega}$	$\hat{\rho}$	$\hat{\varphi}$	LR half life[b]	$\hat{\gamma}$	$\hat{\lambda}$	SR half life	$\hat{\rho} = \hat{\varphi} = 0$	$\hat{\gamma} = \hat{\lambda} = 0$
North									
Canada	0.0009 (0.102)[a]	0.999* (165.9)	0.016 (1.529)	692	0.132* (2.118)	0.162 (0.443)	0.56	29006.13*	5.993**
Mexico	0.001*** (1.6)	0.997* (609.9)	-0.007 (-0.728)	231	0.440* (5.884)	0.366* (5.949)	3.21	523465.4*	169.03*
Central									
Costa Rica	0.0002 (1.198)	0.977* (47.292)	0.190* (3.572)	29.78	0.291* (4.263)	0.009 (0.073)	0.57	3310.08*	18.47*
El Salvador	0.0001* (3.450)	0.939* (40.917)	0.186* (4.315)	11.01	-0.014* (-2.035)	-0.976* (-61.57)	69	1674.48*	7573.22*
Guatemala	0.0002* (6.157)	0.908* (19.063)	0.118* (2.020)	7.18	0.079 (1.006)	0.112 (0.154)	0.42	460.02*	1.029
Honduras	0.00007* (3.26)	0.970* (59.382)	0.098* (3.273)	22.75	0.167* (2.766)	-0.220 (-0.819)	0.23	3840.99*	3840.99*
Nicaragua	0.0002* (2.143)	0.940* (48.728)	-0.557* (-2.742)	11.20	0.846* (5.681)	0.084 (0.173)	10	37730.76*	1138332*
Panama	0.00002* (7.76)	0.962* (42.323)	0.017 (0.969)	17.89	0.196* (2.583)	0.142 (0.653)	0.64	1878.95*	7.89**
Caribbean									
Dom. Rep.	0.006 (0.083)	0.997* (40.650)	0.272* (8.033)	231	-0.019 (-1.332)	-0.914* (-17.69)	9.84	2011.62*	785.70*
Jamaica	0.0002* (3.670)	0.754* (2.831)	0.904 (0.290)	2.45	-0.469 (-0.152)	1.063 (0.286)	1.33	109.18*	14.63*
Trinidad T.	0.0001* (3.262)	0.962* (53.658)	0.128* (2.751)	17.89	0.035 (0.571)	0.578 (0.812)	1.42	3033.75*	0.83
South									
Argentina	0.022 (0.089)	0.997* (40.598)	0.284* (6.558)	231	0.105* (1.794)	-0.521*** (-1.7)	0.79	3846.65*	17.30*
Brazil	0.001 (0.411)	0.999* (484.09)	0.159* (8.340)	692	0.075 (0.043)	0.436 (1.012)	1.03	23582.1*	4.80***
Chile	-0.001 (0.614)	0.999* (20756)	-0.004* (-24.44)	692	0.156* (11.42)	0.756* (35.39)	7.52	590000*	27941.80*
Colombia	0.004 (0.204)	0.999* (219.23)	0.119* (3.637)	692	0.472* (6.486)	0.026 (0.222)	0.99	53920*	46.94*
Ecuador	0.003 (0.742)	0.999* (2134.4)	0.221* (5.564)	692	0.241* (5.001)	-0.053 (-0.392)	0.41	4559045*	40.54*
Paraguay	0.0006* (3.523)	0.963* (50.87)	0.087* (3.365)	18.38	0.189* (3.141)	0.144 (0.671)	0.63	2638.90*	12.19*
Peru	0.004 (0.213)	0.999* (223.06)	0.321* (8.204)	692	0.353* (7.626)	0.192* (1.850)	1.14	52811.58*	116.45*
Uruguay	0.013 (0.218)	0.998* (190.84)	0.263* (9.007)	346	0.023 (1.451)	-0.932* (-18.16)	7.26	36884.18*	811.56*
Venezuela	-0.003 (-0.260)	0.999* (213.14)	0.213* (4.122)	692	0.387* (5.688)	0.111 (0.765)	0.99	55512.98*	32.49*

Notes:

a. Parentheses are used to indicate z-statistics. *, **, *** indicate significance at 1%, 5% and 10%, respectively.

b. The long-run and short-run half-lives are measured using the following formulae: $LR_{HL}(\hat{\rho}) = Ln(1/2)/Ln(\hat{\rho})$ and $SR_{HL}(\hat{\gamma}+\hat{\lambda}) = Ln(1/2)/Ln(\hat{\gamma}+\hat{\lambda})$.

c. Wald tests on coefficient restrictions are Chi-square statistics with 2 degrees of freedom.

Table 2b. Volatility C-GARCH Model Estimates: Europe

	Permanent Component				Transitory Component			Wald Tests[c]	
	$\hat{\omega}$	$\hat{\rho}$	$\hat{\varphi}$	LR half life[b]	$\hat{\gamma}$	$\hat{\lambda}$	SR half life	$\hat{\rho} = \hat{\varphi} = 0$	$\hat{\gamma} = \hat{\lambda} = 0$
European Union									
EU-12	0.0008* (2.64)[a]	0.981* (91.89)	0.075* (3.38)	36	0.063 (1.037)	-0.209 (-0.297)	0.36	8476.96*	1.30
Austria	0.0007* (9.727)	0.980* (187.22)	-0.009 (-0.222)	34	0.053 (1.349)	0.877* (10.55)	9.55	35084.91*	112.48*
Belgium	0.0007* (6.997)	0.972* (119.90)	0.027** (1.742)	24.40	0.089 (1.352)	-0.138 (-0.349)	0.23	14718.09*	2.08
Denmark	0.0007* (6.998)	0.983* (195.02)	0.007 (0.282)	40.42	0.052*** (1.64)	0.8405* (5.222)	6	38049.57*	38.33*
Finland	0.003 (1.169)	0.999* (930.48)	0.033* (3.526)	692	0.105* (4.328)	-0.838* (-10.94)	2.24	894369.1*	254.39*
France	0.004* (3.541)	0.999* (3624.8)	0.087* (5.057)	692	0.100* (2.968)	-0.526* (2.133)	0.81	13210952*	24.34*
Germany	0.0007* (9.154)	0.980* (167.26)	-0.009 (-0.287)	34.30	0.073* (2.111)	0.844* (12.143)	8	28339.69*	150.54*
Greece	0.0007* (50.71)	0.989* (1782.5)	-0.032* (-28.12)	62.66	0.086* (2.780)	0.710* (5.452)	3	48651090*	80.59*
Italy	0.0009* (101.1)	0.992* (45802)	-0.030* (-8.193)	86.29	0.134* (3.258)	0.593* (4.415)	2.17	12400000*	106.12*
Ireland	0.0007* (2.838)	0.980* (77.84)	0.072* (3.026)	34	-0.093** (-1.74)	0.227 (0.371)	0.34	6086.87*	3.27
Netherlands	0.0007* (7.988)	0.982* (192.82)	0.003 (0.154)	38.16	0.078** (1.707)	0.763* (3.648)	4	37502.63*	52.05*
Portugal	0.0007* (7.756)	0.973* (48.32)	0.013 (0.862)	25.32	0.185* (2.755)	-0.116 (-0.594)	0.25	2335.74	7.89**
Spain	0.0008* (33.13)	0.992 (6243.3)	-0.015* (-3.29)	86.29	0.147* (2.673)	-0.020 (-0.114)	0.33	39298467*	7.17**
Sweden	0.0007* (10.55)	0.983* (263.44)	0.002 (0.331)	40	0.206* (3.624)	-0.160 (-0.947)	0.22	70547.28*	15.47*
United K.	0.0007* (4.948)	0.976* (89.56)	0.037* (1.854)	28.53	0.243* (3.656)	-0.004 (-0.020)	0.48	8200.69*	13.45*
Central and Eastern									
Czech Rep.	0.0005 (0.320)	0.999* (549.64)	0.165* (7.638)	692	0.040 (1.045)	-0.828* (-4.176)	2.9	319447.7*	45.11*
Hungary	0.005* (3.554)	0.998* (3268)	0.053* (4.615)	346	0.160* (4.485)	-0.651* (-5.207)	0.95	11139857	191.53*
Poland	0.003* (1.980)	0.999* (1174.6)	0.090* (10.733)	692	0.258* (7.496)	-0.035 (-0.228)	0.46	1380914	56.40*
Others									
Norway	0.0006* (8.443)	0.966 (84.18)	0.013 (0.643)	20	0.191* (3.415)	0.310*** (1.62)	1	7722.33*	20.79*
Russia	0.0004*** (1.6)	0.928* (23.91)	0.306* (2.073)	9.27	0.394* (4.930)	0.394* (4.930)	0.58	729.12*	25.47*
Switzerland	0.0008* (9.557)	0.975* (134.66)	0.013 (1.316)	27.37	0.057 (1.455)	-0.766* (-3.607)	2	20275.78*	28.02*
Turkey	0.001* (13.47)	0.445 (0.195)	-0.913 (-0.011)	0.85	1.194 (0.014)	-0.802 (-0.010)	0.74	3.75	3.35

Notes: a. Parentheses are used to indicate z-statistics. *, **, *** indicate significance at 1%, 5% and 10%, respectively.

b. The long-run and short-run half-lives are measured using the following formulae: $LR_{HL}(\hat{\rho}) = Ln(1/2\ )/Ln(\hat{\rho})$ and $SR_{HL}(\hat{\gamma}+\hat{\lambda}) = Ln(1/2\ / Ln(\hat{\gamma}+\hat{\lambda})$.

c. Wald tests on coefficient restrictions are Chi-square statistics with 2 degrees of freedom.

Table 2c. Volatility C-GARCH Model Estimates: Middle East

	Permanent Component				Transitory Component			Wald Tests[c]	
	$\hat{\omega}$	$\hat{\rho}$	$\hat{\varphi}$	LR half life[b]	$\hat{\gamma}$	$\hat{\lambda}$	SR half life	$\hat{\rho} = \hat{\varphi} = 0$	$\hat{\gamma} = \hat{\lambda} = 0$
Israel	0.0004* (5.54)[a]	0.908* (21.74)	0.262 (1.116)	7.18	-0.238 (-1.047)	1.018* (2.949)	2.79	1365.24*	135.78*
Jordan	0.0002* (4.21)	0.977* (122.03)	0.067* (2.066)	29.78	0.046 (0.895)	0.572 (0.885)	1.44	18709.23*	3.05
Kuwait	0.0002* (5.62)	0.977* (173.33)	0.041* (2.629)	29.78	0.139* (3.602)	-0.609* (-3.682)	0.91	32396.31*	61.61*
Syria	0.0004* (17.8)	0.547 (0.268)	0.0122 (0.164)	1.15	0.134 (0.066)	-0.504* (-5.340)	0.70	1.37	272.06*
Saudi Arabia	0.00005 (1.31)	0.979* (45.98)	0.158 (1.288)	32.66	0.034 (1.288)	-0.949* (-16.34)	7.80	2223.80*	853.06*

Notes:

a. Parentheses are used to indicate z-statistics. *, **, *** indicate significance at 1%, 5% and 10%, respectively.
b. The long-run and short-run half-lives are measured using the following formulae: $LR_{HL}(\hat{\rho}) = Ln(1/2)/Ln(\hat{\rho})$ and $SR_{HL}(\hat{\gamma}+\hat{\lambda}) = Ln(1/2)/Ln(\hat{\gamma}+\hat{\lambda})$.
c. Wald tests on coefficient restrictions are Chi-square statistics with 2 degrees of freedom.

Table 2d. Volatility C-GARCH Model Estimates: Oceania

	Permanent Component				Transitory Component			Wald Tests[c]	
	$\hat{\omega}$	$\hat{\rho}$	$\hat{\varphi}$	LR half life[b]	$\hat{\gamma}$	$\hat{\lambda}$	SR half life	$\hat{\rho} = \hat{\varphi} = 0$	$\hat{\gamma} = \hat{\lambda} = 0$
Australia	0.007 (0.420)[a]	0.998* (363.92)	0.152* (4.983)	346	0.154* (4.073)	-0.381* (-2.001)	0.47	132868.8*	22.86*
New Zealand	0.001* (4.512)	0.971* (92.653)	0.065* (2.410)	0.76	0.113* (1.943)	0.292 (0.873)	0.76	11852.60*	5.09***

Notes:

a. Parentheses are used to indicate z-statistics. *, **, *** indicate significance at 1%, 5% and 10%, respectively.
b. The long-run and short-run half-lives are measured using the following formulae: $LR_{HL}(\hat{\rho}) = Ln(1/2)/Ln(\hat{\rho})$ and $SR_{HL}(\hat{\gamma}+\hat{\lambda}) = Ln(1/2)/Ln(\hat{\gamma}+\hat{\lambda})$.
c. Wald tests on coefficient restrictions are Chi-square statistics with 2 degrees of freedom.

Table 2e. Volatility C-GARCH Model Estimates: Asia

	Permanent Component				Transitory Component			Wald Tests[c]	
	$\hat{\omega}$	$\hat{\rho}$	$\hat{\varphi}$	LR half life[b]	$\hat{\gamma}$	$\hat{\lambda}$	SR half life	$\hat{\rho} = \hat{\varphi} = 0$	$\hat{\gamma} = \hat{\lambda} = 0$
North									
Bangladesh	0.0038 (0.108)[a]	0.998* (78.64)	0.236* (6.206)	346	0.065 (1.133)	0.205 (0.404)	0.33	6374.09*	1.33
India	0.0003* (3.734)	0.902* (21.35)	0.259* (3.925)	6.72	0.041 (1.444)	-0.867* (-8.153)	3.62	472.17*	168.47*
Indonesia	0.0007 (0.668)	0.996* (164.21)	0.100* (3.560)	173	0.472* (12.72)	0.123* (2.150)	1.33	46983.69*	197.99*
Malaysia	0.0025 (0.138)	0.999* (147.42)	0.159 (0.028)	692	0.151* (2.955)	-0.389 (-1.529)	0.48	22345.02*	42.54*
Pakistan	0.0004* (4.598)	0.971* (0.010)	0.042* (2.766)	23.55	0.336* (4.846)	0.097 (0.769)	0.77	9351.14*	25.08*
Philippines	0.0003*** (1.6)	0.971* (53.68)	0.139* (2.195)	24.40	0.318* (5.119)	0.008 (0.061)	0.62	3417.36*	26.25*
Singapore	0.0002* (8.679)	0.804* (5.118)	1.430 (0.077)	317	-1.403 (-0.076)	2.189 (0.118)	2.38	113.16*	75.86*
Sri Lanka	0.0003* (22.91)	0.970* (111.36)	-0.052* (5.131)	22.75	0.457* (5.131)	0.168*** (1.69)	1.47	76478.44*	39.70*
Thailand	0.0002*** (1.6)	0.975* (46.05)	0.161* (4.056)	23.37	0.074 (1.282)	-0.511 (-1.070)	0.84	2122.65*	9.86*
South									
China	0.0001 (1.231)	0.956* (28.78)	0.356* (3.757)	15.40	0.384* (77.18)	0.075 (0.708)	0.89	3395.64*	3056.62*
Hong Kong	0.00007* (6.36)	0.936* (11.77)	0.092 (0.345)	10.48	0.028 (0.109)	0.805 (0.974)	3.79	1123.73*	2.52
Japan	0.0008* (11.72)	0.962* (110.92)	0.012 (0.904)	17.89	0.151* (2.865)	-0.384* (-1.991)	0.47	14230.64*	17.22*
Korea	0.0002*** (1.6)	0.989* (143.71)	0.072* (3.191)	62.66	0.315* (5.291)	-0.341* (-3.549)	0.19	24982.51*	197.32*
Taiwan	0.0002* (40.58)	0.986* (1091.5)	-0.029* (-29.42)	49.16	0.149* (3.411)	0.500* (3.791)	1.60	37202054*	83.31*

Notes:

a. Parentheses are used to indicate z-statistics. *, **, *** indicate significance at 1%, 5% and 10%, respectively.

b. The long-run and short-run half-lives are measured using the following formulae: $LR_{HL}(\hat{\rho}) = Ln(1/2)/Ln(\hat{\rho})$ and $SR_{HL}(\hat{\gamma}+\hat{\lambda}) = Ln(1/2)/Ln(\hat{\gamma}+\hat{\lambda})$.

c. Wald tests on coefficient restrictions are Chi-square statistics with 2 degrees of freedom

Table 2f. Volatility C-GARCH Model Estimates: Africa

	Permanent Component				Transitory Component			Wald Tests[c]	
	$\hat{\omega}$	$\hat{\rho}$	$\hat{\varphi}$	LR half life[b]	$\hat{\gamma}$	$\hat{\lambda}$	SR half life	$\hat{\rho} = \hat{\varphi} = 0$	$\hat{\gamma} = \hat{\lambda} = 0$
North									
Algeria	0.0007* (3.81)[a]	0.979* (103.22)	0.0581* (2.686)	32.65	0.115* (1.922)	0.059 (0.460)	0.39	10655.96*	3.77
Egypt	0.029 (0.249)	0.998* (194.90)	0.474 (0.048)	346	0.187* (4.748)	-0.381* (-5.255)	0.42	38106.97*	58.91*
Morocco	0.0004* (9.73)	0.939* (24.67)	0.034* (1.814)	11	0.046* (2.535)	-0.960* (-35.14)	7.70	814.28*	3019.44*
Tunisia	0.0005* (7.639)	0.975* (147.55)	0.0007 (0.031)	27.37	0.201* (3.230)	0.579* (4.866)	2.79	23307.10	71.02*
Sub-Saharan									
Benin	0.014* (4.731)	0.999* (19760)	0.070* (5.245)	692	0.123* (3.454)	-0.690* (-4.685)	1.22	39000000*	84.92*
Cameroon	0.0008* (7.244)	0.975* (89.69)	0.018 (0.783)	27.37	0.079 (1.554)	0.610* (2.018)	1.86	8272.13*	13.13*
Congo	0.0013* (27.08)	0.981* (380.58)	-0.021* (-3.662)	36.13	0.259* (4.423)	0.226* (2.063)	0.96	149811.9*	30.07*
Cote d'Ivoire	0.0009* (8.249)	0.755* (8.648)	2.728 (0.319)	2.46	-2.665 (-0.312)	3.405 (0.399)	2.30	115.63*	89.76*
Ghana	0.018 (0.245)	0.999* (239.42)	0.269* (10.63)	692	0.317* (7.598)	-0.060 (-0.684)	0.51	62734.08*	101.72*
Kenya	0.0006* (3.928)	0.958* (50.89)	0.107* (3.814)	16.15	0.229* (4.194)	-0.219* (-2.147)	0.15	2749.57*	41.64*
Mozambique	0.0008 (0.892)	0.984* (54.90)	0.169* (3.012)	43	0.375* (6.000)	-0.073 (-0.564)	0.58	4319.73*	44.12*
Nigeria	0.001* (2.412)	0.972* (53.21)	0.103 (1.431)	24.40	0.184* (2.297)	0.557* (3.208)	0.70	2908.21*	20.81*
Senegal	0.0010* (7.345)	0.913* (20.95)	1.160* (8.480)	7.61	-1.149* (-7.689)	2.056* (19.04)	7.1	3771.02*	3535.18*
Sierra Leone	0.0032* (19.32)	0.993* (745.40)	-0.241* (-8.537)	98.67	0.651* (128.62)	0.312* (276.20)	17.9	593796.9*	100769.9*
South Africa	0.0032 (0.283)	0.997* (127.23)	0.076* (3.489)	230	0.220* (4.119)	-0.148 (-1.011)	0.26	23789.22*	22.10*
Tanzania	0.0009* (10.27)	0.951* (72.59)	0.028* (2.279)	230	0.216* (4.082)	-0.237** (-1.73)	0.18	7727.32*	40.08*
Zambia	0.003* (71.57)	0.998* (73788)	-0.038* (-99.28)	346	0.466* (8.662)	0.158*** (1.6)	1.46	5.52000000*	899.76*

Notes:

a. Parentheses are used to indicate z-statistics. *, **, *** indicate significance at 1%, 5% and 10%, respectivel
b. The long-run and short-run half-lives are measured using the following formulae: $LR_{HL}(\hat{\rho}) = Ln(1/2)/Ln(\hat{\rho})$ and $SR_{HL}(\hat{\gamma}+\hat{\lambda}) = Ln(1/2)/Ln(\hat{\gamma}+\hat{\lambda})$.
c. Wald tests on coefficient restrictions are Chi-square statistics with 2 degrees of freedom.

Table 3. Summary: Number and Percentage of Significant Coefficient Estimates

	$\hat{\omega}$	$\hat{\rho}$	$\hat{\varphi}$	$\hat{\gamma}$	$\hat{\lambda}$
America (20 countries)	9/20 (45%)	20/20 (100%)	16/20 (80%)	14/20 (70%)	7/20 (35%)
Europe (EU-12+ 21 countries)	20/22 (91%)	21/22 (95%)	13/22 (60%)	16/22 (72%)	13/22 (59%)
Middle East (5 countries)	4/5 (80%)	4/5 (80%)	2/5 (40%)	1/5 (20%)	4/5 (80%)
Oceania (2 countries)	1/2 (50%)	2/2 (100%)	2/2 (100%)	2/2 (100%)	1/2 (50%)
Asia (14 countries)	10/14 (71%)	14/14(100%)	11/14 (78%)	9/14 (64%)	6/14 (43%)
Africa (17 countries)	13/17 (76%)	17/17(100%)	12/17 (70%)	15/17 (88%)	12/17 (70%)

run volatility persistence. The coefficient estimates suggest the long-run volatility persistence is very high in North and South American countries (being the long-run component half-life decay 692 months in seven cases). Finally, the coefficient $\hat{\varphi}$, that gives the initial effect of a shock to the long-run component, it is significant in sixteen out of the twenty cases. Regarding the transitory component, the coefficient $\hat{\gamma}$ is significant in fourteen out of twenty total cases and the coefficient $\hat{\lambda}$, which indicates the degree of memory in the transitory component, is significant in seven cases. Shock persistence in the transitory component, measure by $(\hat{\varphi}+\hat{\gamma})$, is small in a large number of cases. So, the short-run component half-life decay is less or around one month for all countries being 3.21 months for Mexico, 69 months for El Salvador, 9.9 for Nicaragua, 9.84 for the Dominican Republic, 7.52 for Chile and 7.26 for Uruguay.

In the case of the European countries, the permanent component, $\hat{\omega}$ is significant for almost all countries, while the coefficient $\hat{\rho}$ is significant for all countries (except for Turkey) confirming the presence of long-run volatility persistence. Moreover, the long-run volatility persistence is very high for Finland, France and the three Central and Eastern European countries. The coefficient $\hat{\varphi}$ is significant in thirteen out of the twenty two cases. In the transitory component, the coefficient $\hat{\gamma}$ is significant in sixteen out of twenty two total cases and the coefficient $\hat{\lambda}$ is significant in thirteen out of total examined cases. The short-run component half-life decay is smaller than four months for all countries except for Austria, Denmark and Germany.

Concerning the Middle East countries, the estimated coefficients for $\hat{\omega}$ and $\hat{\rho}$ are significant at 1% in four out of five total cases. The long-run component half-life decay oscillates from 32.66 to 1 month for Syria. Moreover, the coefficient $\hat{\varphi}$ is significant in two cases. Regarding the transitory component, the coefficient $\hat{\gamma}$ is significant in one out of five total cases and the coefficient $\hat{\lambda}$ is significant in four out of five examined cases. The short-run component half-life decay oscillates between 7.80 and 0.70 months.

As for the permanent component for Asia, results indicate that $\hat{\omega}$, is significant in ten out of fourteen examined cases. The coefficient $\hat{\rho}$ is significant for all countries. In addition, the long-run volatility persistence oscillates between 0.999 and 0.804. The coefficient $\hat{\varphi}$ is significant in eleven out of the fourteen examined cases. In the transitory component, the coefficient $\hat{\gamma}$ is significant in nine out of fourteen total cases and the coefficient $\hat{\lambda}$ is significant in six cases.

As regards as Oceania, the coefficient $\hat{\rho}$ is significant for Australia and New Zealand at the 1% of significant, being the long-run volatility persistence very high in Australia (half-life decay 346 months).

Finally, for African countries, regarding the permanent component, the long-run average volatility ($\hat{\omega}$) is significant in thirteen out of the seventeen cases examined. The coefficient $\hat{\rho}$ is significant for all countries at the 1% of significant. Moreover, the coefficient estimates suggest the long-run volatility persistence is very high in seven countries (with the long-run component half-life decay oscillating between 692 and 98.67 months). The coefficient $\hat{\varphi}$ is significant in twelve out of the seventeen total cases. In addition, the coefficient $\hat{\gamma}$ is significant in fifteen out of seventeen total cases and the coefficient $\hat{\lambda}$ is significant in twelve cases. Shock persistence in the transitory component is small in a large number of cases. So, the short-run component half-life decay is around one or two months for all countries being 7.70 for Morocco and 17.9 for Sierra Leone.

In order to evaluate the empirical relevance of our analysis, we compare the performance of the C-GARCH model to the GARCH model. It is worth noting that the C-GARCH model reduces to the GARCH (1, 1) model either $\hat{\omega}$ = $\hat{\rho}$ =0 or $\hat{\gamma}$ = $\hat{\lambda}$ = 0. On the basis of Wald tests on these coefficients, we can see the null hypothesis is decisively rejected in almost all cases in favor of C-GARCH specification over the GARCH(1,1) specification, giving further support for our specification strategy.

Summarizing, our empirical results suggest that there exists a permanent-transitory component decomposition for our set of real exchange rates. Furthermore, we could obtain graphically additional information from Figures 1-6. These figures plot the estimated of the total conditional variance and its two components, the permanent and transitory, of the monthly difference in real exchange rate for all countries under study. Two regularities look to appear: (1) there is a change in volatility when a financial crisis occurs: sometimes the permanent component has smooth movements around the total GARCH volatility while the transitory component raises and other times the three volatilities (the total GARCH permanent and transitory) move together during

Figure 1. Total, permanent and transitory variance of real exchange rates in America

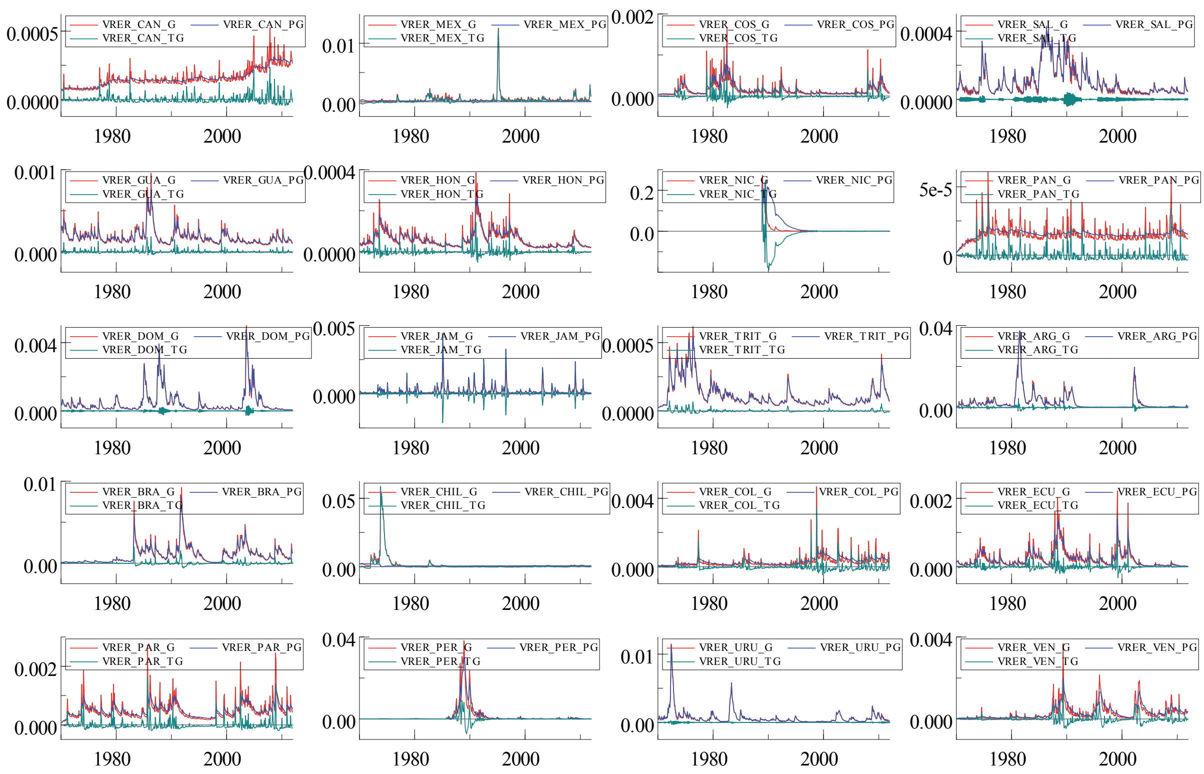


Figure 2. Total, permanent and transitory variance of real exchange rates in Europe

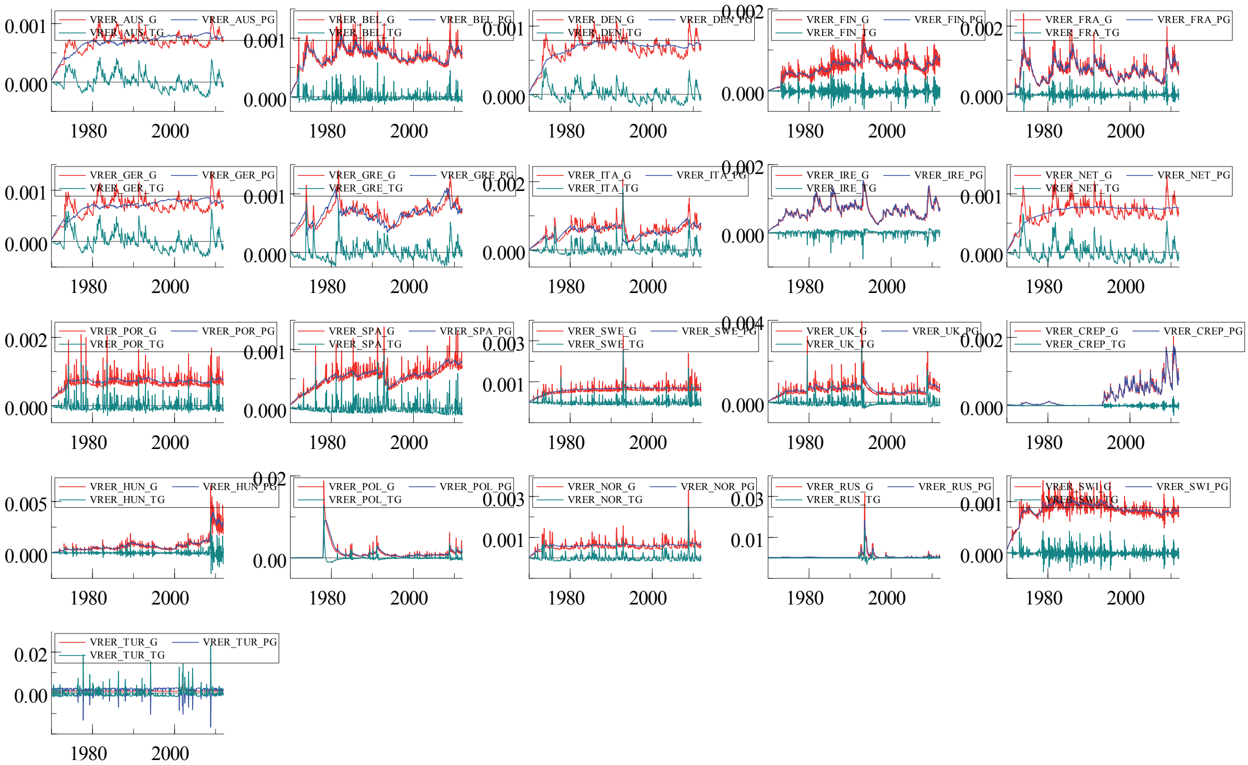


Figure 3. Total, permanent and transitory variance of real exchange rates in Middle East

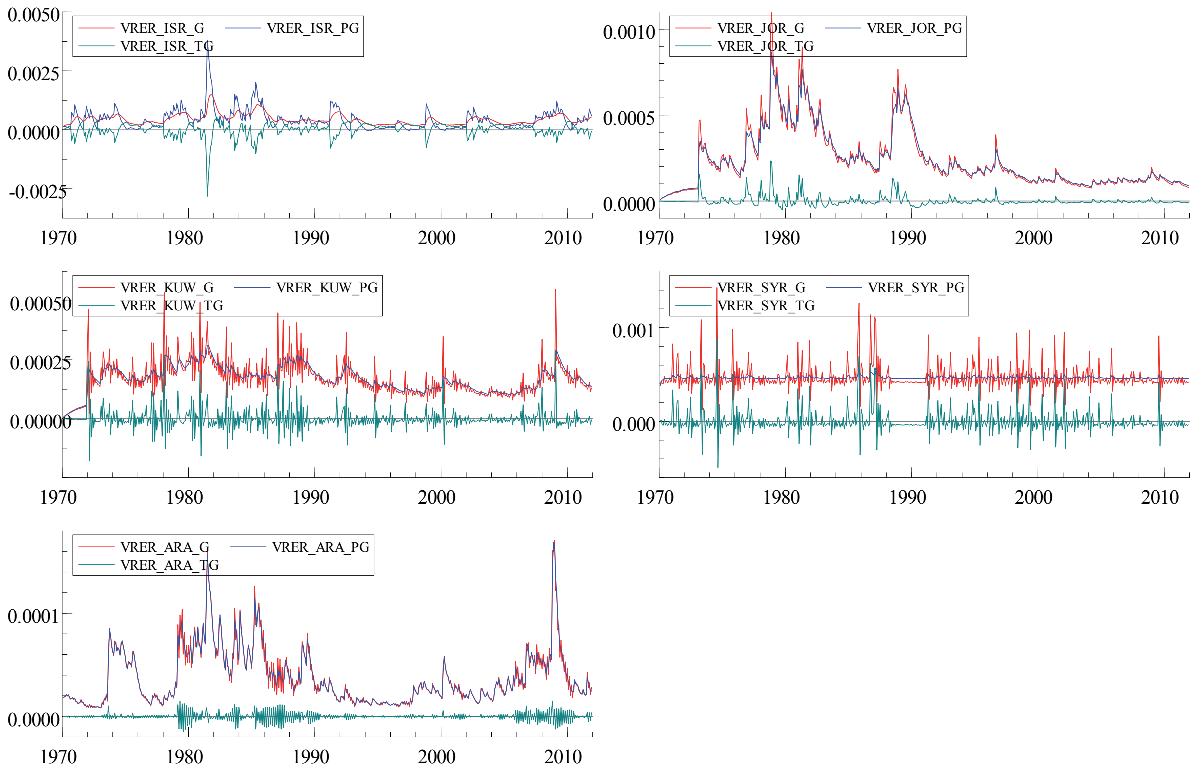


Figure 4. Total, permanent and transitory variance of real exchange rates in Oceania

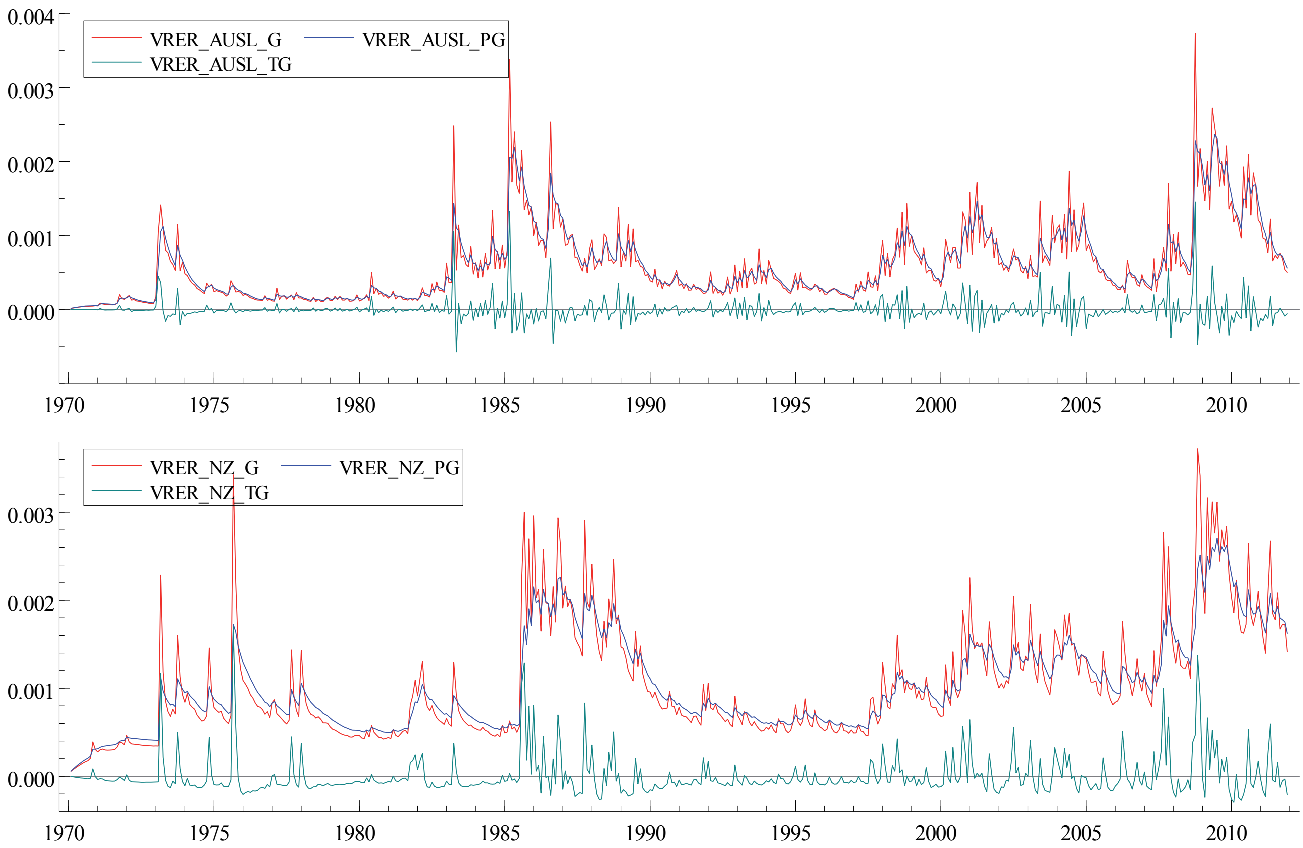


Figure 5. Total, permanent and transitory variance of real exchange rates in Asia

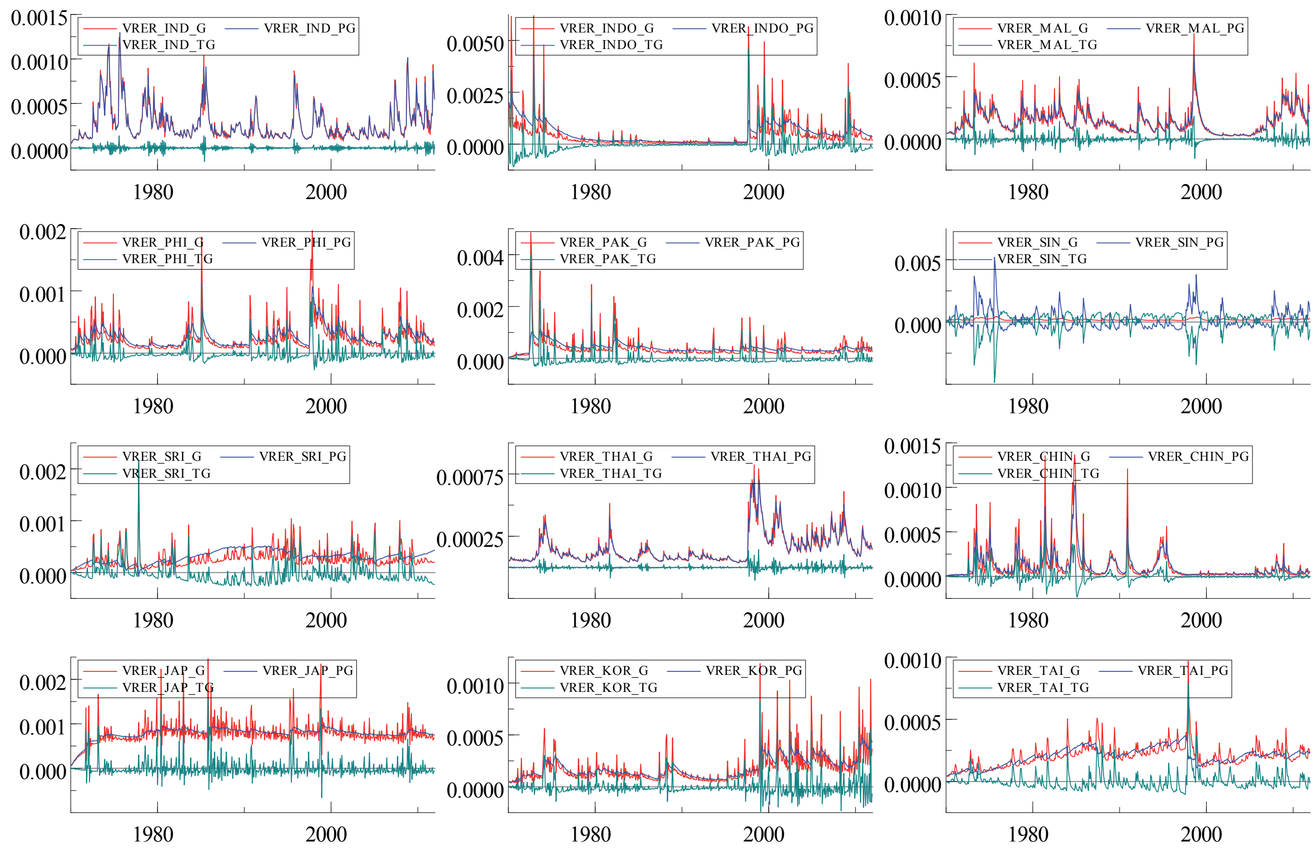
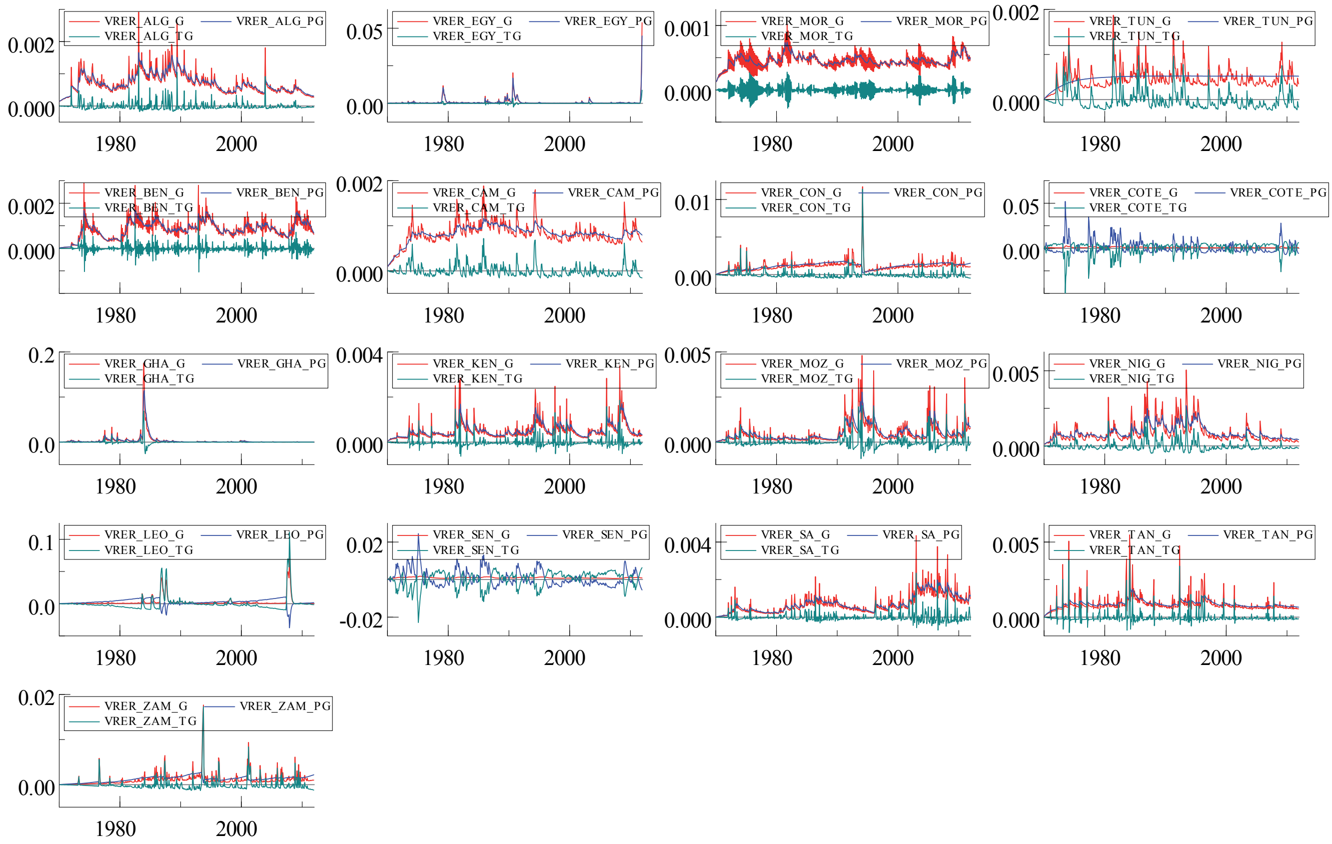


Figure 6. Total, permanent and transitory variance of real exchange rates in Africa



a financial crisis; and (2) it looks that the transitory component is much more volatile, responding largely to economic events. Taken together, these findings imply that during financial crises, exchange rates are determined not only by traditional factors but also, to a major extent, by subjective perception of market participants.

Finally, and in line with Sarno and Valente (2006), a pattern seems to emerge relating countries with long periods of fixed exchange rate regimes and higher degree of persistence in RER volatility.

To explore more formally the visual information provided in Figures 1-6, we further analyze the connection between the behaviour of the permanent/transitory components with both the occurrence of a change in the nominal exchange rate regime and the existence of a SBC and/or a CC and/or a DC. Tables 4a-e and 5a-e show the results. In the first column of Tables 4a-e we present the dating of financial crises using the information provided by Laeven and Valencia (2008) and Reinhart (2010). In the first column of Tables 5a-e we present the structural breaks associated with a change in the nominal exchange rate regime. In the second column of Tables 4 and 5, we present the results of three variance equality tests (VET): the Barllet test, the Levene test and the Brown-Forsythe test.[10]

Findings indicate that, in general, RER volatility change when there is a variation in the nominal exchange rate and after the occurrence of a financial crisis. Indeed, we observe that for almost all countries, and in almost all variations in the nominal exchange rate regime and financial crises, volatility equality tests reject the null hypothesis of equal variances. It is worth noting that for the European Union countries, there is some evidence in favour of a change in RER volatility during the recent global crisis in the cases

[10] For details see Sokal and Rohlf (1995), Levene (1960), Conover, *et al.* (1981), Brown and Forsythe (1974a, 1974b) and Neter, *et al.* (1996).

Table 4a. Permanent and Transitory Components: America

	Financial Crisis Dates[a]	VET[b]		
		Bartlett	Levene	B-F
North				
Canada	-	-		
Mexico	SBC: 1981, 1994; CC: 1977, 1982, 1995; DC: 1982	1977: 199.81(0.000)	8.74 (0.003)	5.28 (0.022)
		1981-82: 184.51 (0.000)	5.54 (0.018)	3.40 (0.065)
		1994-95: 241.21 (0.000)	9.69 (0.002)	4.48 (0.034)
Central				
Costa Rica	SBC: 1987, 1994; CC:1981, 1991; DC: 1981	1981: 3.97 (0.046)	6.77 (0.009)	5.79 (0.016)
		1987: 93.50 (0.000)	47.98 (0.000)	29.61 (0.000)
		1991-94: 49.26 (0.000)	24.31 (0.000)	14.67 (0.000)
El Salvador	SBC: 1989; CC: 1986	1986-89: 39.17 (0.000)	41.26 (0.000)	25.64 (0.000)
Guatemala	SBC: 2006, CC: 1986	1986: 114.7 (0.000)	39.16 (0.000)	19.58 (0.000)
		2006: 42.65 (0.000)	8.90 (0.003)	5.34 (0.021)
Honduras	CC: 1990; DC: 1981	1981: 14.52 (0.000)	2.33 (0.126)	0.707 (0.400)
		1990: 38.62 (0.000)	17.35 (0.000)	9.26 (0.025)
Nicaragua	SBC: 1996, 2000; CC:1990	1990: 618.57 (0.000)	474.45 (0.000)	413.7 (0.000)
		1996: 1630.0 (0.000)	109.11 (0.000)	32.36 (0.000)
		2000: 1415.8 (0.000)	52.09 (0.000)	15.72 (0.000)
Panama	SBC: 1988; DC: 1983	1983: 32.80 (0.000)	13.22 (0.000)	15.42 (0.000)
		1988: 11.25 (0.000)	3.63 (0.057)	5.57 (0.018)
Caribbean				
Dom. Rep.	SBC: 2003; CC: 1985, 1990, 2003; DC: 1982, 2003	1982-85: 92.26 (0.000)	36.96 (0.000)	13.59 (0.000)
		1990: 4.27 (0.038)	0.015 (0.902)	0.553 (0.457)
		2003: 1.94(0.162)	0.838 (0.360)	0.247 (0.619)
Jamaica	SBC: 1996; CC: 1978, 1983, 1991; DC: 1978	1978: 90.45 (0.000)	13.16 (0.000)	5.77 (0.016)
		1983: 153.1 (0.000)	23.88 (0.000)	10.30 (0.001)
		1991: 0.233 (0.628)	0.629 (0.428)	0.338 (0.560)
		1996: 43.3(0.000)	9.62 (0.002)	4.53 (0.033)
Trinidad T.	CC: 1986, DC: 1989	1986-89: 157.72 (0.000)	114.46(0.000)	70.94 (0.000)

Notes:

a. Financial crisis dates from Laeven and Valencia (2008) and Reinhart (2010)

b. b. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

Table 4a. Permanent and Transitory Components: America (cont.)

	Financial Crisis Dates[a]	VET[b]		
		Bartlett	Levene	B-F
South				
Argentina	SBC: 1980, 1989, 1995, 2001; CC: 1975, 1981, 1987, 2002; DC: 1982, 2001	1975: 134.4 (0.00)	17.99 (0.000)	6.89 (0.008)
		1980-81-82: 164. 5 (0.000)	30.17 (0.000)	11.12 (0.000)
		1987-89: 128 (0.000)	29.25 (0.000)	21.4 (0.000)
		1995		
		2001-02: 332.2 (0.000)	44.05 (0.000)	24.89 (0.000)
Brazil	SBC: 1990, 1994; CC: 1976, 1982, 1987, 1992; 1999; DC:1983	1976: 397.38 (0.000)	61.70 (0.000)	49.27 (0.000)
		1982-83: 19.43 (0.000)	25.12 (0.000)	29.83 (0.000)
		1987:16.49 (0.000)	3.91 (0.048)	8.02 (0.004)
		1990-92-94: 49.08 (0.000)	14.03 (0.000)	5.45 (0.019)
		1999: 37.4 (0.000)	9.01 (0.002)	2.65 (0.103)
Chile	SBC: 1976, 1981; CC: 1972, 1982; DC: 1983	1972: 27.6 (0.000)	0.006 (0.980)	0.188 (0.664)
		1976: 1876 (0.000)	271.8 (0.000)	130.7 (0.000)
		1981-83: 1964.09 (0.000)	131.59 (0.000)	56.41 (0.000)
Colombia	SBC: 1998	1998: 129 (0.000)	36.34 (0.000)	21.75 (0.000)
Ecuador	SBC: 1982, 1998; CC: 1982, 1999; DC: 1982, 1999	1982: 98.65 (0.000)	28.25(0.000)	18.05 (0.000)
		1998-99: 20.90 (0.000)	11.68(0.000)	11.25 (0.000)
Paraguay	SBC: 1995; CC: 1984, 1989, 2002; DC:1982	1982-84: 30.20 (0.000)	15.50(0.000)	10.94 (0.000)
		1989: 2.45 (0.117)	2.89 (0.089)	2.07 (0.150)
		1995: 5.18 (0.022)	2.45 (0.117)	1.83 (0.176)
		2002: 0.959 (0.327)	0.177(0.673)	0.161 (0.688)
Peru	SBC: 1983; CC: 1976, 1981, 1988; DC: 1978	1976-78: 937.02 (0.000)	31.49 (0.000)	10.04 (0.000)
		1981-83: 1425.35 (0.000)	57.23 (0.000)	18.56 (0.000)
		1988: 28.50 (0.000)	3.67 (0.055)	0.458 (0.498)
Uruguay	SBC: 1981, 2002; CC: 1972, 1983, 1990, 2002; DC: 1983, 2002	1972: 345.03 (0.000)	237.51(0.000)	89.08 (0.000)
		1981-83: 504.08 (0.000)	94.33 (0.000)	44.86 (0.000)
		1990:9 334.98 (0.000)	41.59 (0.000)	19.47 (0.000)
		2002: 116.19 (0.000)	9.21 (0.002)	3.88 (0.049)
Venezuela	SBC: 1994; CC: 1984, 1989, 1994, 2002; DC: 1982	1982-84: 450.6 (0.000)	112.76(0.000)	74.01 (0.000)
		1989: 2.738(0.085)	1.608 (0.205)	6.43 (0.011)
		1994: 0.908 (0.340)	6.89 (0.008)	9.605 (0.002)
		2002: 4.283 (0.004)	1.461 (0.227)	0.060 (0.805)

Notes:

a. Financial crisis dates from Laeven and Valencia (2008) and Reinhart (2010)

b. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

Table 4b. Permanent and Transitory Components: Europe

	Financial Crisis Dates[a]	VET[b]		
		Bartlett	Levene	B-F
European Union				
EU-12	-	-		
Austria	SBC: 2008	2008: 8.05 (0.004)	1.40(0.236)	1.32 (0.250)
Belgium	SBC: 2008	2008: 13.39 (0.000)	5.31 (0.021)	6.12 (0.013)
Denmark	SBC: 2008	2008: 6.96 (0.008)	0.901 (0.342)	0.776 (0.378)
Finland	SBC: 1991; CC: 1993	1991-93: 52.31 (0.000)	29.26 (0.000)	29.56 (0.000)
France	-	-		
Germany	SBC: 2007	2007: 0.020 (0.886)	0.456 (0.499)	0.209 (0.647)
Greece	CC: 1983	1983: 43.23 (0.000)	50.19 (0.000)	44.40 (0.000)
Italy	SBC: 2008; CC: 1981	1981: 0.955 (0.328)	5.271 (0.022)	4.133 (0.042)
		2008: 0.272 (0.601)	0.028 (0.865)	0.444 (0.505)
Ireland	SBC: 2007	2007: 0.001 (0.967)	0.317 (0.573)	0.293 (0.588)
Netherlands	SBC: 2008	2008: 4.601 (0.031)	0.562 (0.453)	0.293 (0.588)
Portugal	CC: 1983	1983: 53.72 (0.000)	7.96 (0.005)	10.19 (0.001)
Spain	SBC: 1977, 2008; CC: 1983	1977: 4.183 (0.040)	2.982 (0.084)	1.763 (0.184)
		1983: 2.36 5(0.124)	3.85 (0.050)	4.671 (0.031)
		2008: 3.941 (0.047)	2.99 1(0.084)	5.384 (0.020)
Sweden	SBC: 1991; CC: 1993	1991-93: 20.27 (0.000)	1.072 (0.3000)	2.863 (0.091)
United K.	SBC: 2007	2007: 2.197 (0.138)	3.463 (0.063)	1.992 (0.158)
Central and Eastern				
Czech Rep.	SBC: 1996	1996: 347.78 (0.000)	168.88 (0.000)	118.80 (0.000)
Hungary	SBC: 1991, 2008	1991: 348.47 (0.000)	91.73 (0.000)	45.82 (0.000)
		2008: 81.92 (0.000)	92.78 (0.000)	72.37 (0.000)
Poland	SBC: 1992; DC: 1981	1981: 499.69 (0.000)	186.47 (0.000)	48.75 (0.000)
		1992: 306.27 (0.000)	58.88 (0.000)	29.62 (0.000)
Others				
Norway	SBC: 1991	1991: 6.73 (0.009)	0.027 (0.867)	0.138 (0.709)
Russia	SBC: 1998; CC: 1988; DC: 1998	1998: 372.31 (0.000)	14.26 (0.000)	3.70 (0.000)
Switzerland	-	-		
Turkey	SBC: 1982, 2000; CC: 1978, 1984, 1991, 1996, 2001; DC: 1978	1978: 0.701 (0.000)	0.028 (0.865)	0.0006 (0.980)
		1982-84: 4.94 (0.026)	0.0006 (0.978)	0.046 (0.828)
		1991: 22.20 (0.000)	1.68 (0.194)	0.376 (0.540)
		1996: 22.17 (0.000)	3.72 (0.054)	1.41 (0.234)
		2000-01: 28.35 (0.000)	6.86 (0.009)	3.93 (0.047)

Notes: Financial crisis dates from Laeven and Valencia (2008) and Reinhart (2010); b. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

Table 4c. Permanent and Transitory Components: Middle East and Oceania

	Financial Crisis Dates[a]	VET[b]		
		Bartlett	Levene	B-F
Middle East				
Israel	SBC: 1977; CC: 1975, 1980, 1985	1975-77: 31.71 (0.000)	9.44 (0.000)	6.94 (0.008)
		1980: 29.30 (0.000)	8.03 (0.004)	5.28 (0.021)
		1985: 23.18 (0.000)	6.60 (0.010)	6.80 (0.009)
Jordan	SBC: 1989; CC: 1989; DC: 1989	1989: 422.4(0.000)	266.3 (0.000)	197.2 (0.000)
Kuwait	SBC: 1982	1982: 37.09(0.000)	25.33 (0.000)	26.62 (0.000)
Syria	CC: 1988	1988: 30.47(0.000)	6.98 (0.000)	3.90 (0.048)
Saudi Arabia	-		-	
Oceania				
Australia	-	-	-	
New Zealand	-		-	

Notes:

a. Financial crisis dates from Laeven and Valencia (2008) and Reinhart (2010)

b. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

Table 4d. Permanent and Transitory Components: Asia

	Financial Crisis Dates[a]	VET[b]		
		Bartlett	Levene	B-F
South				
Bangladesh	SBC: 1987; CC: 1976	1976: 17.82 (0.000)	9.27 (0.002)	11.93 (0.000)
		1987: 509.2 (0.000)	305.0 (0.000)	231.8 (0.000)
India	SBC: 1993	1993: 1.07 (0.300)	2.94 (0.086)	3.36 (0.067)
Indonesia	SBC: 1997; CC: 1979, 1998; DC: 1999	1979: 39.60 (0.000)	8.25 (0.004)	5.63 (0.018)
		1997-98-99: 15.50 (0.000)	0.13 (0.710)	0.030 (0.862)
Malaysia	SBC: 1997; CC: 1998	1997-98: 1.95 (0.162)	8.82 (0.003)	5.54 (0.018)
Pakistan	CC: 1972	1972: 162.08 (0.000)	62.85 (0.000)	14.21 (0.000)
Philippines	SBC: 1983, 1997; CC: 1983, 1998; DC: 1983	1983: 28.41 (0.000)	7.50 (0.006)	3.305 (0.069)
		1997-98: 16.78 (0.000)	2.45 (0.117)	0.610 (0.434)
Singapore	-	-		
Sri Lanka	SBC: 1989; CC: 1978	1978: 42.54 (0.000)	83.55 (0.000)	3.24 (0.072)
		1989: 4.57 (0.032)	0.054 (0.815)	0.024 (0.875)
Thailand	SBC: 1983, 1997; CC: 1998	1983: 72.36 (0.000)	45.13 (0.000)	32.08 (0.000)
		1997-1998: 92.68 (0.000)	74.84 (0.000)	52.87 (0.000)
North				
China	SBC: 1998	1998: 305.12 (0.000)	63.46 (0.000)	33.07 (0.000)
Hong Kong	-	-		
Japan	SBC: 1997	19.06 (0.000)	7.195 (0.007)	7.99 (0.004)
Korea	SBC: 1997; CC: 1998	180.66 (0.000)	73.74 (0.000)	47.20 (0.000)
Taiwan	-	-		

Notes:

a. Financial crisis dates from Laeven and Valencia (2008) and Reinhart (2010)

b. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

Table 4e. Permanent and Transitory Components: Africa

	Financial Crisis Dates[a]	VET[b]		
		Bartlett	Levene	B-F
North				
Algeria	SBC: 1990; CC: 1988, 1994	1988: 29.90 (0.000)	24.87 (0.000)	24.26 (0.000)
		1990: 112.15 (0.000)	68.10 (0.000)	65.09 (0.000)
		1994: 119.74 (0.000)	66.64 (0.000)	61.37 (0.000)
Egypt	SBC: 1980; CC: 1979, 1990; DC: 1984	1979-80: 87.46 (0.000)	1.517 (0.218)	0.518 (0.471)
		1984: 170.10 (0.000)	6.122 (0.013)	2.060 (0.151)
		1990: 89.11 (0.000)	0.0002 (0.987)	0.084 (0.771)
Morocco	SBC: 1980; CC: 1981; DC: 1983	1980-81-83: 62.28 (0.000)	56.40 (0.000)	55.51 (0.000)
Tunisia	SBC: 1991	1991: 28.08 (0.000)	15.99 (0.000)	15.72 (0.000)
Subshaharan				
Benin	SBC: 1988; CC: 1994	1988: 41.87 (0.000)	41.73 (0.000)	42.87 (0.000)
		1994: 51.12 (0.000)	32.66 (0.000)	34.41 (0.000)
Cameroon	SBC: 1987; 1995; CC: 1994; DC: 1989	1987-89: 62.00 (0.000)	43.11 (0.000)	44.73 (0.000)
		1994-95: 112.3 (0.000)	47.20 (0.000)	48.45 (0.000)
Congo	SBC: 1983, 1991, 1994; CC: 1976, 1983; 1989, 1994, 1999; DC: 1976	1976: 8.16 (0.004)	0.121 (0.727)	0.232 (0.629)
		1983: 37.33 (0.000)	0.281 (0.596)	0.025 (0.872)
		1989-91: 77.46 (0.000)	0.858 (0.354)	0.042 (0.837)
		1994: 122.7 (0.000)	10.28 (0.001)	10.03 (0.001)
		1999: 92.42 (0.000)	7.08 (0.008)	9.098 (0.002)
Cote d'Ivoire	SBC: 1988; CC: 1994; DC: 1984, 2001	1984: 105.93 (0.000)	117.28 (0.000)	65.98 (0.000)
		1988: 90.35 (0.000)	86.17 (0.000)	50.97 (0.000)
		1994: 51.41 (0.000)	41.13 (0.000)	24.50 (0.000)
		2001: 14.24 (0.000)	12.83 (0.000)	7.25 (0.000)
Ghana	SBC: 1982; CC: 1978, 1983, 1993, 2000	1978: 134.32 (0.000)	2.48 (0.115)	0.65 (0.417)
		1982-83: 226.74 (0.000)	4.981 (0.027)	0.780 (0.377)
		1993: 1123.84 (0.000)	32.41 (0.000)	15.80 (0.000)
		2000: 1003.04 (0.000)	180.5 (0.000)	8.83 (0.000)
Kenya	SBC: 1985, 1992; CC: 1993	1985: 1.555 (0.212)	1.920 (0.166)	1.704 (0.192)
		1992-93: 32.55 (0.000)	19.11 (0.000)	13.89 (0.000)
Mozambique	SBC: 1987; CC: 1987; DC: 1984	1984: 180.32 (0.000)	57.67 (0.000)	37.10 (0.000)
		1987: 239.69 (0.000)	78.67 (0.000)	53.04 (0.000)
Nigeria	SBC: 1991; CC: 1983, 1989, 1997; DC: 1983	1983: 88.81 (0.000)	56.20 (0.000)	28.38 (0.000)
		1989-91: 0.361 (0.547)	0.010 (0.917)	0.029 (0.864)
		1997: 158.48 (0.000)	82.20 (0.000)	46.27 (0.000)

Table 4e. Permanent and Transitory Components: Africa (cont.)

	Financial Crisis Dates[a]	VET[b]		
		Bartlett	Levene	B-F
Subshaharan				
Senegal	SBC: 1988; CC: 1994; DC: 1981	1981: 40.02 (0.000)	56.13 (0.000)	52.87 (0.000)
		1988: 48.24 (0.000)	51.73 (0.000)	50.81 (0.000)
		1994: 19.05 (0.000)	19.06 (0.000)	21.72 (0.000)
Sierra Leone	SBC: 1990; CC: 1983; 1989; 1998; DC: 1977	1977: 508.95 (0.000)	24.29 (0.000)	8.79 (0.000)
		1983: 359.24 (0.000)	39.26 (0.000)	14.08 (0.000)
		1989-90: 28.85 (0.000)	0.0005 (0.995)	0.017 (0.894)
		1998: 104.35 (0.000)	12.16 (0.000)	2.37 (0.123)
South Africa	CC: 1984; DC: 1985	1984-85: 94.13 (0.000)	51.55 (0.000)	36.21 (0.000)
Tanzania	SBC: 1987; CC: 1985, 1990; DC: 1984	1984-87: 59.76 (0.000)	15.12 (0.000)	10.51 (0.000)
		1990: 39.67 (0.000)	8.46 (0.000)	5.53 (0.000)
Zambia	SBC: 1995; CC: 1983, 1989, 1996; DC: 1983	1983: 171.80 (0.000)	23.57 (0.000)	13.75 (0.000)
		1989: 108.06 (0.000)	9.10 (0.002)	3.37 (0.067)
		1995-96: 29.57 (0.000)	1.76 (0.184)	2.58 (0.108)

Notes:

a. Financial crisis dates from Laeven and Valencia (2008) and Reinhart (2010)

b. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

Table 5a. Permanent and Transitory Components: America

	Structural breaks in nominal exchange rate regimes	VET[a]		
		Bartlett	Levene	B-F
North				
Canada	Nov 2002	66.55 (0.000)	32.72(0.000)	28.63 (0.000)
Mexico	Apr 1981, Mar 1988, Dec 1994	1981: 184.51 (0.000)	5.54 (0.018)	3.40 (0.065)
		1988: 236.75(0.000)	3.310(0.069)	0.773 (0.000)
		1994: 241.21 (0.000)	9.69 (0.002)	4.48 (0.034)
Central				
Costa Rica	**Nov 1983**	1983: 141.81(0.000)	85.364 (0.000)	54.74 (0.000)
El Salvador	-	-		
Guatemala	-	-		
Honduras	**Mar 1990, Dec 1998**	1990: 38.62 (0.000)	17.35 (0.000)	9.26 (0.025)
		1998: 168.11(0.000)	51.855(0.000)	41.58 (0.000)
Nicaragua	**Feb 1992**	1992: 1651.4(0.000)	474.46(0.000)	120.8 (0.000)
Panama	-	-		
Caribbean				
Dom. Rep.	**Jan 1985, Ago 1991, Jan 2005**	1985: 92.26 (0.000)	36.96 (0.000)	13.59 (0.000)
		1991: 14.082(0.000)	6.113 (0.013)	1.250 (0.264)
		2005: 63.57(0.000)	13.64 (0.000)	6.259 (0.012)
Jamaica	**Jan 1983; Jul 1996**	1983: 153.1 (0.000)	23.88 (0.000)	10.30 (0.001)
		1996: 43.3(0.000)	9.62 (0.002)	4.53 (0.033)
Trinidad T.	**May 1976**	122.37(0.000)	140.0(0.000)	124.13 (0.000)
South				
Argentina	Feb 1981, Mar 1991, Oct 2001	1981: 164. 5 (0.00)	30.17 (0.000)	11.11 (0.000)
		1991: 156.13 (0.000)	49.42 (0.000)	34.71 (0.000)
		2001: 332.2 (0.000)	44.05 (0.000)	24.89 (0.000)
Brazil	-	-		
Chile	Jun 1976, Jan 2001	1976: 1876 (0.000)	271.8 (0.000)	130.7 (0.000)
		2001: 749.7 (0.000)	26.66 (0.000)	9.20 (0.000)
Ecuador	Mar 1982, Apr 2001	1982: 98.65 (0.000)	28.25(0.000)	18.05 (0.000)
		2001: 179.28(0.000)	47.76 (0.000)	31.74 (0.000)

Table 5a. Permanent and Transitory Components: America (cont)

Paraguay	Mar 1985, Jan 1991, Mar 2002	1985: 30.20 (0.000)	15.50(0.000)	10.94 (0.000)
		1991: 0.168 (0.681)	0.069 (0.791)	0.033 (0.855)
		2002: 0.959 (0.327)	0.177(0.673)	0.161 (0.688)
Peru	Oct 1977, Ago 1986	1977: 937.02(0.000)	31.49 (0.000)	10.04 (0.000)
		1986: 1193.7(0.000)	73.59 (0.000)	23.69 (0.000)
Uruguay	-		-	
Venezuela	Nov 1986	508.5 (0.000)	127.7 (0.000)	82.64 (0.000)

Note:

a. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

Table 5b. Permanent and Transitory Components: Europe

	Structural breaks in nominal exchange rate regimes	VET[a]		
		Bartlett	Levene	B-F
	European Union			
EU-12	Jan 1980	31.86 (0.000)	31.99 (0.000)	18.64 (0.000)
Austria	Jul 1980	83.14 (0.000)	97.22 (0.000)	59.28 (0.000)
Belgium	-		-	
Denmark	Jan 1980	86.27 (0.000)	110.80 (0.000)	62.24 (0.000)
Finland	-		-	
France	Mar 1979	33.81 (0.000)	4.45(0.000)	26.55(0.000)
Germany	-		-	
Greece	Jul 1981	13.23 (0.000)	19.40 (0.000)	13.41 (0.000)
Italy	-		-	
Ireland	Mar 1979	9.71 (0.001)	2.07 (0.150)	2.96 (0.085)
Netherlands	-		-	
Portugal	Ago 1993	34.41 (0.000)	9.26 (0.005)	10.38 (0.001)
Spain	-		-	
Sweden	-		-	
United K.	Sep 1992	0.986 (0.320)	0.454 (0.500)	0.064 (0.799)
	Central and Eastern			
Czech Rep.	Ago 1981, Mar 1994	1981: 536.37 (0.000)	190.09 (0.000)	182.35 (0.000)
		1994: 689.43 (0.000)	234.61 (0.000)	177.55 (0.000)
Hungary	Jun 1979, Ago 2005	1979: 217.29 (0.000)	34.53 (0.000)	19.21 (0.000)
		2005: 474.37 (0.000)	387.58 (0.000)	283.68 (0.000)
Poland	Oct 1977	848.21 (0.000)	37.41 (0.000)	19.38 (0.000)
	Others			
Norway	SBC: 1991	1992: 1593.73 (0.000)	59.01 (0.000)	26.31 (0.000)
Russia	Jan 1992, Ago 1998, Ago 2005	1998: 372.31 (0.000)	14.26 (0.000)	3.70 (0.000)
		2005: 136.94 (0.000)	3.374 (0.000)	0.674 (0.000)
Switzerland	**-**		-	
Turkey	-		-	

Note:

a. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

Table 5c. Permanent and Transitory Components: Middle East and Oceania

	Structural breaks in nominal exchange rate regimes	VET[a]		
		Bartlett	Levene	B-F
Middle East				
Israel	Oct 1977	1977: 31.71 (0.000)	9.44 (0.000)	6.94 (0.008)
Jordan	Feb 1975, Feb 1990, Ago 1995	1975: 14.05 (0.000)	4.704 (0.000)	3.212(0.000)
		1990: 422.4 (0.000)	266.33(0.000)	197.2 (0.000)
		1995: 380.12(0.000)	212.79(0.000)	135.6 (0.000)
Kuwait	-	-		
Syria	-	-		
Saudi Arabia	-	-		
Oceania				
Australia	Nov 1982	136.35(0.000)	72.48 (0.000)	52.97 (0.000)
New Zealand	Mar 1985	55.84 (0.000)	70.01 (0.000)	56.21 (0.000)

Note:

a. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

Table 5d. Permanent and Transitory Components: Asia

	Structural breaks in nominal exchange rate regimes	VET[a]		
		Bartlett	Levene	B-F
South				
Bangladesh	-	-		
India	Jul 1979, Dec 2004	1979: 42.77 (0.000)	9.232 (0.002)	6.183 (0.013)
		2004: 15.27 (0.000)	4.180 (0.000)	2.031 (0.000)
Indonesia	Jul 1997	15.50 (0.000)	0.13 (0.710)	0.030(0.862)
Malaysia	Jul 1998	1.95 (0.162)	8.82 (0.003)	5.54 (0.018)
Pakistan	Jun 1982	378.42 (0.000)	84.64 (0.000)	42.75 (0.000)
Philippines	Jul 1997	16.78 (0.000)	2.45 (0.117)	0.610 (0.434)
Singapore	-	-		
Sri Lanka	Nov 1981, Sep 1989	1981: 31.81 (0.000)	5.919 (0.015)	2.237 (0.135)
		1989: 4.57 (0.032)	0.054 (0.815)	0.024 (0.875)
Thailand	Jul 1997	92.68 (0.000)	74.84 (0.000)	52.87 (0.000)
North				
China	Jan 1994	183.63 (0.000)	46.43 (0.000)	25.35 (0.000)
Hong Kong	Oct 1983	123.90 (0.000)	73.80(0.000)	49.24 (0.000)
Japan	Nov 1977	0.747 (0.000)	0.947 (0.330)	1.315 (0.251)
Korea	Nov 1997	180.66(0.000)	73.74 (0.000)	47.20 (0.000)
Taiwan	-	-		

Note:

a. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

Table 5e. Permanent and Transitory Components: Africa

	Structural Breaks in nominal exchange rate regimes	VET[a]		
		Bartlett	**Levene**	**B-F**
North				
Algeria	Mar 1994	119.74 (0.000)	66.64 (0.000)	61.37 (0.000)
Egypt	Oct 1991	89.11 (0.000)	0.0002 (0.987)	0.084 (0.771)
Morocco	-	-		
Tunisia	-	-		
Subshaharan				
Benin	-	-		
Cameroon	Dec 1994	112.3 (0.000)	47.20 (0.000)	48.45 (0.000)
Congo	Mar 1976	8.16 (0.004)	0.121 (0.727)	0.232 (0.629)
Cote d'Ivoire	-	-		
Ghana	Sep 1987	1493 (0.000)	54.12 (0.000)	26.06 (0.000)
Kenya	Dec 1978	56.02 (0.000)	19.55 (0.000)	12.26 (0.000)
Mozambique	-	-		
Nigeria	Sep 1984, Mar 1996	1984: 71.19 (0.000)	48.28 (0.000)	23.85 (0.000)
		1996: 179.47 (0.000)	95.41 (0.000)	53.86 (0.000)
Subshaharan				
Senegal	Nov 1994	19.05 (0.000)	19.06 (0.000)	21.72 (0.000)
Sierra Leone	-	-		
South Africa	Jan 1979	81.74 (0.000)	46.82 (0.000)	30.35 (0.000)
Tanzania	Jan 1979	5.198 (0.000)	0.079 (0.000)	0.417 (0.518)
Zambia	Jul 1976, Jul1983	1976: 212.37 (0.000)	21.87 (0.000)	14.01 (0.000)
		1983: 171.80 (0.000)	23.57 (0.000)	13.75 (0.000)

Notes:

a. Volatility equality tests (VET): Bartlett, Levene and Brown-Forsythe tests (p-values in brackets).

of Belgium (a country with a high public debt to GDP ratio) and Spain (a country with a high deficit/GDP ratio).

To gain further insights in the behaviour of the permanent and transitory components of the conditional variance, we examine the correlation coefficients between each series. The results, not shown here to save space but available from the authors upon request, suggest a limited degree of co-movement for the permanent components in all countries under study (with low correlation coefficients) and a still weaker correlations between the transitory components. There is only evidence of relevant correlations between the permanent components for European Union countries, suggesting the existence of some degree of commonality between them. This could be reflecting the closer economic and monetary cooperation between European countries that formally started in 1979 with the ERM and culminated in 1999 with the introduction of a single currency and a common monetary policy.

4. Concluding Remarks

Real exchange rate (RER) volatility is an issue of great importance to both businesses and policymakers. Empirical evidence of the existence of structural breaks in financial time series made this area of research very active in the recent years. A lot of attention in the literature has been given to structural breaks in volatility, which imply changes in the risk behaviour of investors due to important financial events, such as the 1987 stock market crash, the dot-com bubble in 1995-2000 and the subprime mortgage crisis.

The purpose of our paper has been to contribute to the debate on the possible role of nominal exchange rate regimes and financial crises to explain structural breaks in RER volatility. To that end, using data for the period 1970 to 2011, we have first examined the instability in terms of multiple structural breaks in the variance in the time series of eighty countries compromising American, European, Middle East, Oceania, Asian and African countries. In particular, we have presented the results of applying two alternative procedures for searching endogenously without using a priori information: the OLS-based tests to detect multiple structural breaks, proposed by Bai and Perron (1998, 2003) and several procedures based on Information Criterion joint with the so called sequential procedure suggested by Bai and Perron (2003). We then employ the component GARCH model proposed by Engle and Lee (1999) to decompose volatility into a permanent long-run trend component and a transitory short-run component that is mean-reverting towards the long-run trend.

The main results are as follows. Firstly, we found substantial evidence of structural breaks in volatility across investigated RER. Secondly, there is high heterogeneity between series regarding the dates in which the break points are located, although major financial crises seem to provide reasonable explanations for them. Thirdly, and in line with previous empirical research (see, e. g., Mussa, 1986; Baxter and Stockman, 1989; Flood and Rose, 1995; or Rogers, 1995), we document an inverse relationship between the degree of flexibility in the exchange rate regime and RER volatility. Finally, the decomposition of total volatility into its components suggest that the permanent component tracks total RER volatility reflecting the evolution of fundamental factors and the transitory component responds largely to market expectations, rising during the detected structural breaks.

Therefore, regarding financial crisis, our results suggest that, in a context of increasing interconnectedness of financial institutions and markets, RER volatility is exacerbated during crisis periods. This conclusion is consistent with the so-called “third generation models” of currency crisis, that emphasizes the role of the financial sector in causing currency crises and propagating their effects. Different third generation models offer various mechanisms through which distortions in financial markets and banking systems may lead to a currency crisis (see, for example, McKinnon and Pill, 1995; Krugman, 1999; Dooley, 2000, or Chang and Velasco, 2001).

Furthermore, as for nominal exchange rate regime, our results suggest the existence of an inverse relationship between the degree of flexibility in the exchange rate regime and RER using a *de facto* exchange rate classification to correct for possible inconsistencies between the commitment of the central bank and its observed behaviour.

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